Annual Report 2008









RAND PROJECT AIR FORCE

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Annual Report 2008

PROJECT AIR FORCE

About RAND Project AIR FORCE

The mission of RAND Project AIR FORCE (PAF), a division of the RAND Corporation and the Air Force's federally funded research and development center for studies and analyses, is to undertake an integrated program of objective, independent analysis on issues of enduring concern to Air Force leaders. PAF addresses far-reaching and interrelated questions: What will be the role of air and space power in the future security environment? How should the force be modernized to meet changing operational demands? What should be the size and characteristics of the workforce? How can that workforce be most effectively recruited, trained, and retained? How should sustainment, acquisition, and infrastructure be streamlined to control costs?

PAF carries out its research agenda in four programs that represent core competencies:

Strategy and Doctrine seeks to increase knowledge and understanding of geopolitical and other problems in the national security environment that affect Air Force operations. PAF maintains expertise in defense strategy; regional analysis; the objectives and tasks of evolving joint operations; and the potential contributions of air and space power to joint operations, defense planning, and requirements for force development.

Force Modernization and Employment identifies and assesses ways in which technological advances and new operational concepts can improve the Air Force's ability to satisfy a range of future operational demands. This research involves assessments of technology feasibility, performance, cost, and risk. PAF assesses major force components needed in the future and the systems and infrastructure supporting their operations.

Manpower, Personnel, and Training concentrates on questions about workforce size and composition and about the best ways to recruit, train, develop, pay, promote, and retain personnel. PAF's research encompasses the total workforce: active-duty, guard, reserve, civilian, and contractor personnel.

Resource Management analyzes policies and practices in the areas of logistics and readiness; outsourcing, privatization, and contracting; the industrial base; planning, programming, and budgeting; infrastructure; and weapon-system cost estimating. The goal of this program is to maximize the efficiency and effectiveness of Air Force operations in a resource-constrained environment.

PAF also conducts research on topics that cut across all four programs, and its research staff regularly responds to Air Force requests for help on time-urgent problems.

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Message from the Director

Andrew R. Hoehn

Balancing among missions and across time—present and future—has been a hallmark of Air Force leadership since its earliest days. In the 1950s, this meant building a strategic deterrent against Soviet aggression while fighting in Northeast Asia and deterring war in Europe. In the 1960s, this meant supporting the war effort in Vietnam, strengthening the strategic deterrent with land-based intercontinental ballistic missiles, and preparing to modernize the fighter force. In the 1970s and 1980s, this meant completing planned modernization efforts and substantially strengthening conventional forces in Europe while investing in future capabilities driven by stealth and precision. In the 1990s, it meant consolidating the force; building expeditionary capabilities to sustain long-term commitments that lasted into this decade; and preparing to modernize to meet future needs. Looking back, many of these attempts to strike balances among missions and across time may appear to have been straightforward, and the decisions taken may seem to have been appropriate to the challenges the Air Force confronted. But of course, none of this was easy or at all straightforward at the time, just as decisions today are neither easy nor straightforward.

Today the Air Force needs to concentrate on three key challenges: meeting and adapting to the demands of irregular warfare, contending with the threat of regional powers with nuclear weapons, and managing large-scale competition with emerging rivals.

Irregular warfare—primarily in Iraq and Afghanistan but also wherever radical Islam challenges important U.S. interests—presents the most significant near-term challenge. The Air Force plays critical roles in contending with irregular challenges and has fielded an array of new capabilities to meet these challenges. Air Force contributions in surveillance and intelligence, mobility, close air support, and command and control have been crucial to supporting the current fight. In Iraq and Afghanistan, airpower is saving the lives of U.S. military personnel and civilians in combat zones every day. Air Force support to U.S. ground forces has helped bring relief to a variety of stressed career fields in the U.S. Army and the Marine Corps. In the months and years to come, the U.S. response to irregular warfare challenges can and should change, with a shift toward more-indirect roles, which would likely lead the Air

Analysis will remain a key instrument in helping the Air Force make choices: about itself, about its role as a joint partner, about its contributions to broader U.S. national security.

Force to turn its emphasis toward training, equipping, advising, and assisting the forces of friendly governments and away from more-direct counterinsurgency roles.

Looming just over the horizon is the very real prospect of a second nuclear age, a new era of nuclear proliferation. Every effort aimed at halting or countering nuclear proliferation should continue in earnest, but these efforts still may not succeed, and a new era of nuclear proliferation could well ensue. This would not only deeply influence U.S. security policy in general but would also greatly affect how the Air Force organizes itself and operates in the world. Issues surrounding nuclear weapons and their employment could well reenter the national security debate in ways they have not since the waning days of the Cold War. This debate, however, will be different because the challenges potential new nuclear powers—such as North Korea and Iran—pose are assuredly different from those that the Soviet Union posed. The significance of these matters for the Air Force cannot be overstated.

Beyond this, managing competitions with emerging rivals to the United States will be an ever-present aspect of the Air Force's future. Of greatest concern, China continues to grow in economic power and military might. The prospect of a direct confrontation, although unlikely, remains daunting. China's military capabilities continue to grow in numbers and sophistication. More than a decade of rapid growth in Chinese military spending is now producing impressive and concerning results. This investment is yielding new forms of capabilities for which the United States and its allies do not have ready answers—capabilities that could be destabilizing in a future crisis. It is also creating competition—both symmetric and asymmetric—in such familiar areas as offensive and defensive counterair operations and such less-familiar realms as space and cyber. The implications for the Air Force are profound, and these various areas of competition will continue to produce pacing threats for decades to come. Moreover, arms sales and technology transfers will likely spread the capabilities that China and others are producing across the globe.

In the wake of its invasion of Georgia, a resurgent Russia presents a different kind of challenge. In many ways, Russia's military performance was not impressive but is a clear reminder that military clashes cannot be ruled out in areas where the United States and its NATO allies are in the process of defining important, long-term interests. Moreover, despite evidence of weaknesses in the training and readiness of Russian forces, Russia's military technology is often state of the art and is generally available to those with the means to purchase it. Russia will continue to pursue military technological prowess, and this too will remain a concern for the United States and its allies long into the future.

And so the Air Force is in the process of adjusting: to meet the challenges of irregular warfare, not just in Iraq and Afghanistan but elsewhere; to restore focus on the enormous dangers nuclear weapons pose, developing the leadership and body of thought to contend with likely nuclear challenges; and finally, to be on the technological and conceptual front lines, guiding and shaping various competitions with new rivals through

investments in technology and exploration of concepts for protecting key American interests throughout the globe.

This adjustment process will require a concerted and sustained effort at balancing across and among many competing needs—across missions, career fields, and fighting and support organizations and among technologies, forces, and capabilities. There is no single answer or solution. Once a new balance is struck, it will need to be examined and adjusted regularly. Triggering events may require much more fundamental reviews, as indeed is happening now. Resource constraints—human and capital—will of course make the balancing all the harder. Hence, the essence of strategy: focusing resources to meet priority needs.

Analysis will remain a key instrument in helping the Air Force make choices: about itself, about its role as a joint partner, about its contributions to broader U.S. national security. Balancing among missions and across time presents enormous difficulties and poses many risks. Analysis can help identify better options among difficult choices and can shape a better understanding of how risks are managed and adjudicated over time. For more than 60 years, RAND Project AIR FORCE and Air Force leaders have been partners in exploring alternatives, shaping choices, and identifying the consequences of various decisions that have been taken. From the realm of strategy, to force employment and modernization, to manpower and training, to logistics and resource management, Project AIR FORCE continues to partner with the Air Force to address the most difficult challenges the institution and the nation face.

This annual report highlights some of these challenges and attempts, in brief, to show how Project AIR FORCE teams with Air Force leaders to contend with an array of difficult problems. The report pays special attention to the people who make up Project AIR FORCE and the work they do for the institution we serve. It is their focus on the challenges the Air Force and the nation confront and their commitment to quality and objectivity that have made the partnership between RAND and the United States Air Force so special for so long.

Andrew R. Hoehn
Vice President, RAND Corporation
Director, Project AIR FORCE

Nuclear-Armed Regional Adversaries

How Deterrable Are They Likely to Be?

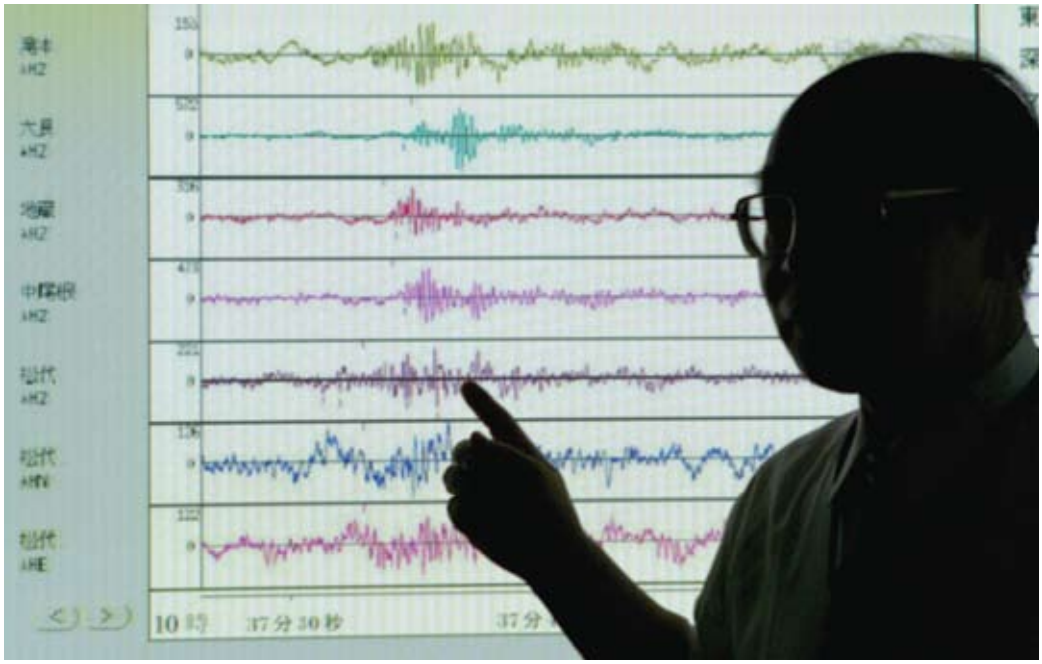
On October 9, 2006, North Korea tested its first nuclear device. Granted, the explosive yield of the device (at an estimated half kiloton of TNT) was not impressive by the standards of most nuclear weapons. Nevertheless, the fact that an impoverished nation-state could develop and test a nuclear device in the face of opposition from all its neighbors in northeast Asia and from the United States is a signal event in international relations. If the United States and other members of the international community are unsuccessful in their efforts to convince North Korea, Iran, and other states to forgo the development of nuclear weapons, the consequences for U.S. and allied security could be profound. Prudence dictates that the United States and its allies prepare for the possibility that they might confront regional adversaries with deliverable nuclear arsenals in the not-too-distant future.

In anticipation of this possibility, a team of Project AIR FORCE (PAF) researchers has been examining the problems nuclear-armed regional adversaries pose for the United States—security challenges that are quite different from those of the Cold War and post–Cold War eras. A recent PAF report by RAND's David Ochmanek and Lowell H. Schwartz, *The Challenge of Nuclear-Armed Regional Adversaries*, documents this work and strongly suggests that it would be a mistake to assume that deterring nuclear-armed regional adversaries will be simply a "lesser included case" of deterring more-powerful adversaries, such as the Soviet Union during the Cold War.

The research team defined *regional adversaries* to mean countries (a) that pursue policies at odds with the interests of the United States and its security partners and that run counter to broadly accepted norms of state behavior and (b) whose size and military forces are not of the first magnitude. The second qualifier is necessary because it distinguishes this group of states from larger, more-powerful potential adversaries, such as Russia or China.

To address this challenge, Ochmanek and his research team sought to answer important questions about U.S. strategy for power-projection operations and about the adequacy of the capabilities that may be available to future U.S. forces:

Iran tests its Shahab-3 missile on July 9, 2008, as shown in an online photo. The weapon reportedly has a range of 1,250 miles and is armed with a one-ton conventional warhead.



Above: In silhouette, a Japan Meteorological Agency staff member points to the graphic record of a magnitude 4.9 earthquake in the northeast region of North Korea on October 9, 2006, occurring in the same area and coinciding with the nuclear weapon test Pyongyang claims to have conducted.

Opposite: Satellite imagery shows the area near where North Korea is believed to have tested its nuclear device in October 2006. Although the explosive yield was not impressive, this was an important step in North Korea's development as a potential nuclear regional power.

- How might nuclear weapons affect the behavior of regional adversaries in peacetime, crisis, and conflict?
- What are the likely ramifications of this development for U.S. security and defense planning?

Nuclear-Armed Regional Adversaries Have Multiple Motivations

It is important to understand both what distinguishes nuclear-armed regional adversaries from other state adversaries and the motivations for pursuing nuclear weapons. Nuclear weapons may be seen as serving a number of purposes. Iran, for example, is thought to be pursuing them to

- deter military threats or attacks by the United States and, perhaps, others
- redress its military inferiority vis-à-vis Israel, Pakistan, India, and Russia—neighboring states that possess nuclear weapons
- enhance national prestige and influence
- shore up domestic political support
- ensure the survival of the regime in the event of war.

The North Korean regime undoubtedly shares most of these motivations. It also might see its nuclear program as a source of leverage against the United States, Japan, South Korea, and China in an effort to extract economic assistance.

U.S. Deterrence Strategies May Not Work

U.S. conventional and nuclear forces will continue to have deterrent effects on the leaders of regional adversary states, such as North Korea and Iran, even if these states field substantial numbers of nuclear weapons. However, defense planners in the United States and elsewhere must

begin now to confront the possibility that, in the face of superior U.S. conventional forces, adversaries of this class could consider using nuclear weapons to be an attractive option (or at least less unattractive than not using them) under a variety of circumstances during a conflict involving the United States.

Several reasons exist for this. First, regional adversary nations spend only a small fraction of what the United States does on military forces (less than 5 percent in the cases of Iran and North Korea). This virtually guarantees that any serious conflict involving the United States that remains conventional will end in defeat for the opponents.

Military defeat can have disastrous consequences for authoritarian rulers, who may therefore be prepared to run high risks to prevent it. Facing the prospect of the downfall of a regime, its leaders may believe using one or more nuclear weapons is the only way to deter the United States and its allies from continuing military operations.

In several recent conflicts, particularly those in Serbia and Iraq, U.S. forces have demonstrated the capability and will to attack enemy leaders, command-and-control assets, weapons of mass destruction, and delivery means from the outset. Fears of decapitation strikes or disarming counterforce attacks could lead enemy leaders to believe that they are in a use-or-lose situation, thus heightening the pressure to use their nuclear weapons early in a conflict.

The U.S. strategy to deter an adversary from using nuclear weapons by threatening retaliation, which was a mainstay of Cold War military strategy, could be highly problematic in many conflict situations involving nuclear-armed regional adversaries. Adversary leaders simply may not believe that they will personally be any worse off for having used nuclear weapons than for not using them.

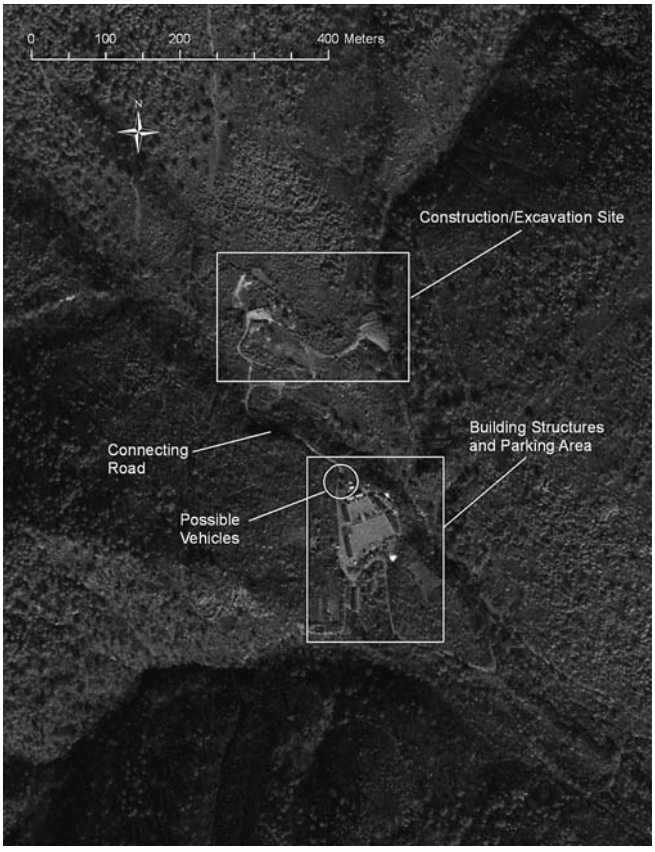
It must be assumed that regional adversaries also will consider using their nuclear weapons simply to threaten or undertake less-consequential attacks against the United States or its allies.

War Gaming Exercises Serve as a Key Analytical Tool

Estimating how a nuclear-armed regional adversary might act under different circumstances is important for determining the types of capabilities that U.S. forces should have in such circumstances. However, it is also, unavoidably, a matter of conjecture.

To understand specific adversaries' objectives, strategies, and perspectives, the research team examined adversary pronouncements and past actions. They also turned to historical examples to gain insights about how other nations behaved in similar situations.

To explore the dynamics of potential crises and conflicts, the research team conducted a series of more than 20 war-gaming exercises involving a nuclear-armed North Korea or Iran. Participants in



U.S. and allied leaders confronting such adversaries will want military capabilities that offer far greater assurance than today's do that adversaries can be prevented—as opposed to deterred—from using nuclear weapons.

the games included numerous military and civilian defense leaders and nongovernmental experts; these served as U.S. policymakers (blue). Adversary (red) moves were, in most cases, devised by the game leaders offline, prior to play. As a result, the researchers were able to assess a wide range of options across a variety of scenarios.

These war-gaming efforts were particularly useful because they helped both researchers and players get beyond "mirror imaging," in which it is implicitly assumed that the enemy will act as U.S. leaders would.

Nuclear-Armed Regional Adversaries Have a Range of Targeting Options

The war games demonstrated that regional adversaries considering potential targets within their regions will have an array of targeting options, the most potent of which may be to threaten to attack major cities or vital economic assets with one or more nuclear weapons. Indeed, a single fission weapon detonated at low altitude over a major city, such as Seoul or Tokyo, could cause well over 100,000 prompt fatalities. A similar attack on the oil export facilities at Dhahran, Saudi Arabia, could severely damage the infrastructure over an area of several square miles.

However, if such an adversary used its nuclear weapons to attack a city or a critical port directly, it likely would be risking massive retaliation from the United States. Therefore, it must be assumed that regional adversaries also will consider using their nuclear weapons to threaten or undertake less-consequential attacks against the United States or its allies. Table 1 lists a variety of ways in which a regional nuclear power with a dozen or so deliverable nuclear weapons could use them other than directly targeting major cities.

For example, an adversary might threaten or attack bases used by the air forces of a neighboring state or the United States, perhaps focusing on bases far removed from population centers. Or it might attempt to attack concentrations of U.S. or allied ground forces in garrisons or in the field. Alternatively, it might elect to detonate a weapon at high

Table 1: Potential Nuclear-Use Options for Regional Adversaries

Objective	Action	Employment Option
Warning	Nuclear demonstration or test	Underground nuclear test Above-ground nuclear test Above-ground nuclear demonstration over adversary's territory (no damage)
Counterforce	Nuclear detonation to disrupt or damage adversary's military forces	Blast causing EMP above air bases Blast causing EMP above naval forces Detonation upwind from air base causing light fallout over base Direct attack on an air base Direct attack on ground forces
Countervalue	Nuclear detonation to damage adversary's civilian infrastructure	Detonation upwind of capital city causing light fallout Blast causing EMP over capital city

altitude so that the electromagnetic pulse (EMP) from the detonation disrupted electronic systems over a wide area but would cause no damage by blast, fire, or radiation. Such threats or attacks might be intended to show resolve and thus dissuade the United States or other opponents from prosecuting military operations against the adversary. Failing this, the attack, if effective, would reduce U.S. capabilities that could be brought to bear against the adversary.

Nuclear-armed regional adversaries can put pressure on the United States and its regional allies by *not* attacking cities and economic infrastructure but holding these assets "hostage" to potential future attacks. The United States may have to choose between accepting a cessation of hostilities well short of success and pressing ahead with military operations but risking hundreds of thousands of civilian casualties and massive destruction.

Iranian President Mahmoud Ahmadinejad addresses a public gathering in the Iranian city of Shahr-e Kord in June 2008, saying that U.S. President George W. Bush had failed in his goals to attack Iran and stop its nuclear program.

Improved Capabilities Are Needed to Prevent Nuclear Attacks

Because U.S. threats of retaliation may fail to deter a nuclear-armed regional adversary in desperate circumstances, U.S. and allied leaders confronting such adversaries will want military capabilities that offer far greater assurance than today's do that adversaries can be *prevented*—as opposed to deterred—from using nuclear weapons. This goal will require U.S. forces that can locate, track, and destroy nuclear weapons and their delivery means before they are launched. Above all, it will require active defenses that can destroy delivery vehicles after they have been launched. Today and for some time to come, the emphasis should be on fielding effective defenses against theater-range ballistic missiles that could be used to deliver nuclear weapons.

Unless and until highly reliable means of attack prevention become available, U.S. leaders will be compelled to temper their objectives vis-à-vis nuclear-armed regional adversaries. It will be necessary either to avoid conflict with them or to use military force in limited ways that minimize the nuclear-armed regional adversary's incentives to escalate to nuclear use.

David Ochmanek

Almost every morning, RAND senior international policy analyst David Ochmanek rides his bike from his home on Capitol Hill to RAND's office near the Pentagon. Not only does his daily commute give him a physical workout, but it also provides some important psychological benefits as well. "My ride gives me an illusory sense of accomplishment before I even start the workday. It helps get me in the right frame of mind to take on the rest of the day," professed Dave, who also serves as the director of the Strategy and Doctrine Program within RAND Project AIR FORCE.

One may question Dave's notion that a daily bike commute through Washington traffic is an *illusory* achievement, but there can be little disputing the influence of his many accomplishments since he first joined RAND in 1985. Having previously served overseas as an Air Force intelligence officer and as a Foreign Service officer, Dave brought with him to RAND an insider's appreciation of both the operational and the foreign policy perspectives of national security challenges. His background proved valuable as he supported or led a variety of research efforts, including studies that assessed the capabilities of U.S. military forces (conventional and nuclear) to achieve campaign objectives, identified priority means for improving the capabilities of NATO's forces in Europe, evaluated the potential effects of proposed arms control agreements and alternative force postures, developed post–Cold War national security strategy options, and explored a wide range of challenges to U.S. security.

During his early years at RAND, when he also served as director of PAF's National Security Strategies Program (the forerunner of today's Strategy and Doctrine Program), Dave and several RAND colleagues, including Peter Wilson and Roger Molander, sought opportunities to incorporate war-gaming exercises in their studies. Such games are usually based on one or more scenarios developed by the study team. Frequently, the games bring together many civilian government officials, military officers, and nongovernmental policy experts who serve as role players for top civilian leaders and senior military commanders.

"We tried to reinvigorate the use of war-gaming in the late 80s and early 90s," Dave explained. "During the later Cold War years, war-gaming largely had been supplanted by the use of complex computer modeling, which assessed the capabilities of U.S. and allied forces against a "scripted" enemy campaign plan. In contrast, gaming helps us better understand red's—the adversary's—perceptions and intentions."

Dave and his PAF colleagues were able to prove the value of gaming as the Air Force was preparing for Operation Desert Storm in fall 1990.

We deliver products that are relevant not only to the Air Force, but also to the broader defense community and the nation as a whole.

PAF was asked to "Red Team" the emerging air campaign plan, called Instant Thunder, which focused heavily on strategic targets in Baghdad. The PAF team tested the campaign plan in a series of war games, which revealed that the strategic strikes alone likely would not be enough to compel Saddam Hussein to withdraw Iraqi forces from Kuwait. The games showed that the United States should conduct relentless aerial bombardment directly against the Iraqi ground forces to break their morale and reduce their capabilities prior to the coalition ground campaign. Insights from PAF's analysis helped the Air Force leadership crystallize in their own minds the value of a more-balanced air campaign against Iraq's military potential. The Air Force adjusted its planning accordingly. "Our work was eerily prescient, as it turned out," Dave said. "The games were almost an exact predictor of how the air campaign would go and how Saddam and his forces would react."

After leaving RAND in 1993 to serve as Deputy Assistant Secretary of Defense for Strategy, Dave realized that he liked analysis more than policy implementation. "Although the Strategy position was a far more interesting opportunity than I expected, in government, you spend too much time arguing with people and not enough time learning about the problems you're supposed to be addressing," he recalled.

Dave returned to RAND in 1995 and has led a variety of projects on trends in the emerging post–Cold War security environment and their implications for U.S. defense strategy, capabilities, and forces. Some of his recent projects have focused on power projection against capable conventionally armed opponents and strategies for countering terrorist groups abroad. Immediately after 9/11, the Air Force Chief of Staff asked PAF to help develop an operational strategy to combat terrorist groups. Dave decided to begin by revisiting case studies of past successful counterinsurgency campaigns. "Terrorism, like insurgency, is a weapon of the weak. Terrorists and insurgents have to rely on stealth to be successful because they can't win a direct confrontation with competent security forces," Dave explained. "For the United States to prevail against such adversaries, we have to keep them under constant pressure. If we can do that, eventually they will make mistakes, which will provide opportunities for us to defeat them. The biggest challenge is to find ways to do this without, at the same time, alienating the local population and turning the people against us and their own governments."

Even as Dave continues to contribute to PAF research efforts, he is serving again as a PAF program director. "As [RAND colleague] Jim Quinlivan says, 'managing at RAND is a bit like being a basketball coach—you help prepare the game plan—in our case, the research agenda—and then you get the ball to the player with the hot hand.' It's much easier when you have a lot of smart people who bring good ideas to the table." And although no trophies are awarded, Dave says it is most rewarding when he and his Strategy and Doctrine team are able "to deliver products that are relevant not only to the Air Force, but also to the broader defense community and the nation as a whole."

For more information, see

MG-671-AF, *The Challenge of Nuclear-Armed Regional Adversaries*, by David Ochmanek and Lowell H. Schwartz. Online at http://www.rand.org/pubs/monographs/MG671/

Sustaining America's Global Reach

The U.S. armed forces are feeling the pressure of sustained combat operations in multiple theaters; increased operational tempo; and growing demands for manpower, equipment, and funding. For the air mobility forces, many of which were acquired in the 1950s, 1960s, and 1970s, the combination of increased tempo and continual aging means that decisions have to be made now about how to modernize.

The Air Force's aerial refueling tankers and airlift fleets enable joint forces to maintain global reach, aerial persistence, and rapid response—critical aspects of our military strategy. The KC-135 aerial refueling tanker fleet is nearly 50 years old and has exhibited some technical difficulties and increased operation and maintenance costs. More than one-third of the Air Force's intratheater airlifters (C-130Es and C-130H1s) are between 30 and 45 years old, and center-wing-box structural fatigue damage has led to either groundings or flight restrictions on many older C-130s.

As operational demands continue to rise, sustaining the required capability with an aging fleet is a challenge. Should new assets be acquired and old ones retired, or should existing assets be refurbished and their service lives extended? If new assets are acquired, what should they be, and when should they be obtained? This is the set of "recapitalization" decisions the Air Force faces today.

Firm Footing Amid Controversy

For many years, PAF has supported recapitalization decisions for aging Air Force aircraft systems. PAF has conducted major studies of tanker and intratheater airlift fleets, in addition to analyses of next-generation gunship capabilities and the replacement of intelligence, surveillance, and reconnaissance platforms. This work provides a firm analytic footing for decisions that are often surrounded by controversy as different factors vie for priority and as aircraft manufacturers compete for substantial contracts. PAF's analytic method levels the playing field between competitors and provides a fair comparison between platforms.

Table 2 illustrates PAF's approach, which consists of the following steps:

A KC-135 Stratotanker undergoes an inspection at Royal Air Force Mildenhall, England. The KC-135 fleet is almost 50 years old and has had some technical difficulties, and its operations and maintenance costs are increasing.

Helping the Air Force Modernize the Aging Air Mobility Fleet

For the air mobility forces, many of which were acquired in the 1950s, 1960s, and 1970s, the combination of increased tempo and continual aging means that decisions have to be made now about how to modernize.

Table 2: The Equal-Effectiveness, Variable-Cost Approach

What is the requirement?	What are the alternatives?	How many of each alternative would be needed to meet the requirement?	How much would each alternative fleet cost?	Which alternative fleet would meet the requirement at lowest cost?
Amounts of fuel or cargo delivered at given times and places	Alternative A	#	$	
	Alternative B	#	$	✔
	Alternative C	#	$	

1. Researchers begin with an operational requirement, which is expressed in terms of what missions the aircraft have to perform. For aerial refueling aircraft, the requirement is defined as the amount of fuel that they must supply, at specific times and locations, to various receiver aircraft. For cargo aircraft, the requirement is defined as the amount of cargo (personnel, supplies, vehicles, fuel, or other) that must be transported specific distances and frequencies to specific kinds of airfields. In the cases of the KC-135 tanker and C-130 intratheater airlift analyses, the Department of Defense set the requirements for the researchers using forecasts of potential future military conflicts.
2. Next, analysts consider the alternatives available, either to replace the current fleet or to implement a service-life extension program to keep existing aircraft viable for several more years. Replacements may be aircraft specifically designed for military use or derivatives of commercial aircraft, which are modified or refitted to perform the required missions.

Above: Fighting Falcons receive fuel from a KC-135 Stratotanker. Aerial refueling enables global reach, aerial persistence, and rapid response.

Opposite: A Kentucky Air National Guard C-130 Hercules completes a major inspection at Ramstein Air Base, Germany. The Air Force is considering whether to extend the service lives of the oldest C-130s or to replace them with other aircraft.

3. Using each aircraft's capabilities, researchers calculate the size of the fleet needed to meet the requirement. Capabilities are determined through analyses of the performance qualities of the aircraft alternatives, such as speed and range-payload characteristics, and through specific mission profiles.
4. Next, the team assesses the cost of each fleet, defined as the present value of all life-cycle costs, including research and development; procurement; military construction; and operations and support, including maintenance, modification, and ultimate disposal costs.
5. Finally, the alternative fleet that can meet the requirement at lowest cost is the most "cost-effective." To account for error, the team identifies a "cost-competitive" set including all fleet alternatives whose costs are within a specified percentage of that of the lowest-cost option.

One advantage of this approach is that it compares fleets rather than individual aircraft, thus considering each alternative's strengths and weaknesses in the context of the total requirement. Researchers examine both *pure fleets* consisting of a single type of aircraft and *mixed fleets* that allow a portion of the requirement to be met by the aircraft best suited to a particular mission. In this way, each aircraft is given the chance to contribute where it is best suited, at the same time that it is compared objectively to other alternatives. Moreover, researchers are able to examine a range of scenarios that put different operational demands on each platform, thus ensuring that an aircraft is not only cost-effective under a specified set of requirements but also able to cost-effectively support different requirement sets that may arise in the future. This approach has earned the PAF team a reputation among both policymakers and the defense industry for objectivity, thoroughness, and fairness.

The long lead-times for funding and implementing acquisition programs mean that the Air Force must continually think far into the future.

A C-130 Hercules from the 2nd Airlift Squadron, Pope Air Force Base, North Carolina, flies over the Atlantic Ocean. The C-130 Hercules primarily performs the intratheater portion of the airlift mission.

Thinking Far Ahead

The cost-analysis approach described here has already helped the Air Force confront several key mobility fleet recapitalization challenges. PAF's analysis of tanker alternatives found that the Air Force should consider a set of medium to large commercial-derivative aircraft from Boeing and Airbus. The Air Force is currently evaluating specific proposals. On the intratheater airlift front, PAF is conducting ongoing research to assess what alternatives are most cost-effective as new mission requirements are defined, including those associated with the continuing war on terror and future global combat scenarios, as well as such missions as domestic disaster relief. Most recently, the Air Force has asked PAF to help analyze alternatives for a possible KC-10 modernization program.

The challenges of sustaining an effective air mobility infrastructure will not be resolved quickly; the long lead-times for funding and implementing acquisition programs mean that the Air Force must continually think far into the future. PAF is helping it do that long-range thinking.

For more information, see

MG-495-AF, *Analysis of Alternatives for KC-135 Recapitalization: Executive Summary*, by Michael Kennedy, Laura H. Baldwin, Michael Boito, Katherine M. Calef, James S. Chow, Joan Cornuet, Mel Eisman, Chris Fitzmartin, Jean R. Gebman, Elham Ghashghai, Jeff Hagen, Thomas Hamilton, Gregory G. Hildebrandt, Yool Kim, Robert S. Leonard, Rosalind Lewis, Elvira N. Loredo, Daniel M. Norton, David T. Orletsky, Harold Scott Perdue, Raymond A. Pyles, Timothy Ramey, Charles Robert Roll, Jr., William Stanley, John Stillion, Fred Timson, and John Tonkinson. Online at http://www.rand.org/pubs/monographs/MG495/

David Orletsky, left, and Michael Kennedy

Michael Kennedy and David Orletsky

Michael Kennedy and David Orletsky have been working together on PAF's aircraft recapitalization studies for several years. Michael is a senior economist based in Santa Monica. With a doctorate from Harvard University and a background teaching economics to students in the Persian Gulf, Michael has spent most of the past 30 years at RAND working on Air Force–related economic analyses. David, who studied aeronautical and astronautical engineering at the Massachusetts Institute of Technology, has 20 years' experience at RAND focusing on aircraft issues and the operational employment of Air Force assets. He is now based in RAND's Washington, D.C., office. Together, Michael and David are part of a large group of researchers on both coasts and in Pittsburgh who help the Air Force identify the most cost-effective options for modernizing aging aircraft fleets.

Being spread out across the country has made it easier for Michael, David, and the team to interact frequently with the contractors who supply data about recapitalization alternatives. "This is a big part of why contractors and clients have confidence in our analyses," says Michael. "The contractors have told us that they view us as honest brokers in the analysis-of-alternatives world. We visit each one several times to make sure that we have the data right and that we are representing their aircraft accurately. They are not always happy with the conclusions of our analyses, but they recognize that we have been open and honest with them in our work and have heard and fairly considered their inputs."

David adds, "Achieving objectivity in comparing different aircraft alternatives requires both good analysis and good professional judgment. To fairly assess different aircraft, we need to ensure that our metrics are appropriate both technically and operationally."

Michael and David themselves represent a blending of perspectives to yield a field of view broader than either has alone. Their backgrounds reflect the multidisciplinary approach that is essential to their analyses' success. Michael points out, "We're not just looking at specs and crunching numbers. We have to understand how each aircraft would perform under real operational conditions." This means ensuring that the analysis takes into account such critical factors as the time urgency of operations, conditions of operating runways, aircrew rotation requirements, hangar requirements, and many others. "These are the things that make the cost-comparison numbers relevant for acquisition decisions," says Michael.

Such an integrated view enables Michael and David to continue to fulfill RAND's mission of providing objective analysis and effective solutions to major policy questions. Moreover, as PAF's staff development and cross-site collaboration team, Michael and David help facilitate the same level of integration among PAF researchers throughout RAND's U.S. and European offices and between senior researchers and students of the Pardee RAND Graduate School. The graduate school grants approximately 20 doctorates in policy analysis each year. "RAND's strength is its ability to form a comprehensive, objective, and realistic view of problems," says Michael. "We are constantly working to keep our perspective as up to date as possible."

On Time and On Budget

Controlling Cost Growth in Air Force Acquisition Programs

Ensuring that the acquisition process leads to the timely development of effective weapon systems without serious cost growth has proved to be one of the military's most difficult and enduring challenges. Even with ongoing efforts to improve the acquisition process, development costs often grow substantially from the time of the original estimate to the time a weapon system program ends. According to a 2007 RAND PAF study of completed weapon system programs from the 1970s, 1980s, and 1990s ("Is Weapon System Cost Growth Increasing?"), their costs, including development, procurement, initial spares and military construction, grew by an average of 46 percent over the estimate at Milestone B (the decision point at which full-scale system development and demonstration begins).

The fact that cost growth continues to be problematic despite the best efforts of the Department of Defense attests to the inherent complexity of the acquisition process and the extremely demanding technological challenges it presents modern weapon system developers and integrators. Indeed, it might be appropriate to celebrate the fact that ongoing vigilance prevents the process from being even more costly, protects the taxpayer's investment, and ensures that our armed services receive the weapon systems they need.

PAF has worked side by side with the Air Force since RAND's incorporation 60 years ago to understand and continuously improve the complex weapon system acquisition process. For example, in a famous 1958 report, *Military Research and Development Policies*, PAF researchers assessed the development histories of post–World War II fighters and bombers, engines, and bombing-navigation systems, demonstrating that a good development policy rests squarely on recognition of research and development as a sequential, iterative, knowledge-building activity. They observed that it is impossible to know exactly how a system will look until the early phases of development have provided reliable test information about the probable performance and cost of any given design. In retrospect, their approach also seems prescient because many of its elements align with what is today called *evolutionary acquisition*, an approach that entails incremental development of weapon capability. But this is only one approach to solving a problem that has many potential causes.

A Delta II rocket carrying a GPS satellite launches from Cape Canaveral Air Force Station, Florida. While the overall GPS program to date boasts a sterling cost-growth record, some of its program subcomponents have not fared so well, having had significant cost growth.

Why Do Weapon Programs Cost More Than Estimated?

Understanding the root causes of cost growth may help the Air Force (and Congress) address flaws in the system and, perhaps more important, lead to wider acceptance that some cost growth is unavoidable on highly complex development programs. A new PAF monograph, *Sources of Weapon System Cost Growth: Analysis of 35 Major Defense Acquisition Programs*, suggests that the causes of cost growth (normalized for inflation) can be organized into three broad categories.

Even with ongoing efforts to improve the acquisition process, development costs often grow substantially from the time of the original estimate to the time a weapon system program ends.

Cost-Estimation Errors

Cost-estimation errors sometimes occur when initial cost estimates are unrealistically optimistic about the financial resources and time needed to complete developmental tasks, even if the program is very well run. Three factors contribute to these errors:

Organizational and bureaucratic factors that encourage overly optimistic Milestone B estimates. Since programs are rarely canceled after reaching Milestone B, an important institutional objective is to win Milestone B approval, even if the program is underfunded. There is a tendency to believe that the program can always "get well" later.

Technological optimism or insufficient accounting for the level of technological uncertainty in developing the system. Uncertainty about the magnitude of the technological task is a feature of many major weapon system programs because those who run them seek large increases in performance capability over prior generations of systems and thus depend on incorporating cutting-edge and often relatively untried technologies, designs, and architectures. Developers and the government can be overly optimistic about how mature a given technology may be, what the technological risks are, and how challenging it will be to integrate complex technology and subsystems into a working system.

Overestimating contractor skills, capabilities, competence, and management expertise. Cost estimators may have credibly assessed the technological difficulty of the project but overestimated the contractor's ability to execute it.

Program Execution

Cost growth may also occur during program execution. If the cost estimation has been realistic, execution problems may not materialize. However, less-than-optimal management during the implementation phase may cause cost growth. Since most development is conducted not under fixed-price but cost-plus-fee contracts (the contractor is paid for the actual costs of development and receives a fee over and above the costs), traditional market forces are less effective after the contract is awarded. Good outcomes require proper guidance, supervision, and motivation of the contractor using a variety of tools and incentives. Recent PAF research (for example, that reported in *Improving the Cost Estimation of Space Systems: Past Lessons and Future Recommendations*) has focused on some of the negative effects of the acquisition reform measures advocated in the early 1990s, which reduced government oversight and guidance but did

Employees at Lockheed Martin paint the first operational F-22 Raptor to be delivered to the Air Force. High technical risk, an artificial distribution of workload among contractors, and other factors led to significant cost growth and schedule delays in the F-22 program.

not provide sufficient incentives for contractors to achieve a satisfactory outcome. Perhaps most damaging were performance requirements that were unclear or that changed frequently. A further complication was the government's failure to prioritize competing requirements.

External Factors

Such external factors as major changes in funding, changes in requirements in response to operational experience or new threats, or increases in required production numbers make up the third category. These program changes are usually made by senior authorities outside the acquisition bureaucracy and often for justifiable reasons. For example, as discussed in the PAF study "Implementing Evolutionary Acquisition: Lessons from Predator and Global Hawk," the large and unanticipated increase in demand for the RQ-1/MQ-1 Predator unmanned aerial vehicle in the global war on terrorism after 9/11 led to a significant increase in production numbers and changes in requirements, greatly increasing program costs but also meeting the much higher demand for the system for the warfighter. This type of cost growth, when based on necessary and justifiable program changes, should not be an area of major concern for cost analysts.

Two Space Programs Highlight the Importance of Appropriate Oversight

PAF has been using these insights to help the Air Force improve its acquisition of major weapon systems. For example, a study of the Air Force

Space and Missile Systems Center (SMC) cost-estimation capabilities showed the importance of government oversight to control the effects of overly optimistic cost estimates and high technological uncertainty. As reported in *Improving the Cost Estimation of Space Systems: Past Lessons and Future Recommendations*, researchers examined two SMC-selected programs: the Space-Based Infrared System–High (SBIRS), which is designed to provide information that supports missile warning, missile defense, battle space characterization, and technical intelligence, and the Global Positioning System (GPS), which is used for positioning, navigation, and timing.

Unusually large cost growth in the SBIRS program is mostly the result of overly optimistic cost estimates at Milestone B and great technological uncertainty.

The SBIRS and GPS programs were conducted under an acquisition reform concept called Total System Program Responsibility. This concept, which transfers much developmental oversight authority to the contractor, was an attempt to reform the acquisition process by making it more "commercial-like." In practice, however, the reform proved inappropriate for the government weapon system acquisition environment. Unusually large cost growth took place in the SBIRS program, most of which can be attributed to overly optimistic cost estimates at Milestone B and great technological uncertainty. GPS performed considerably better, but it also suffered from cost growth in some of its segments, attributable to cost-estimation errors, and from complicated and costly manufacturing process problems that were due in part to mergers and acquisitions in which the prime contractor was involved. Inadequate assessment of technical risk was also a factor. The cost-estimation processes for both programs were too closely associated with bureaucratic interests that held advocacy positions, making independent, disinterested cost analyses more difficult. At the same time, the government did not provide adequate guidance to and oversight of contractors.

PAF concluded that rigorous oversight, monitoring, and assessment of contractor costs and cost data and of technical designs and proposals throughout all phases of the proposal process and program execution are critical for developing credible cost estimates. The difficult balancing act is to develop a collaborative rather than adversarial relationship between contractors and government.

As of 2008, SMC has formally adopted all but one of PAF's recommendations for improving the programs. It has, for example, made the SMC cost and technology risk-assessment functions more independent of program offices. It has also improved the quality of the inputs to the technical assessments by collecting and making available more relevant data and increasing visibility into contractor's capabilities.

While evolutionary acquisition seems sensible in theory, there is little experience with actually implementing it.

Cautious Use of Evolutionary Acquisition May Produce More-Realistic Cost Estimates

Evolutionary acquisition, foreshadowed conceptually in PAF's 1958 research, is now official Department of Defense policy. This acquisition reform measure is in many ways a sensible attempt to correct the problems with cost estimation and implementation that arise from technological uncertainty. In this approach, a weapon system's capabilities are developed incrementally, allowing useful system capabilities to be fielded more quickly. Simply put, a large, complex developmental task, called "single step to full capability," is broken up into a series of smaller, less-complex but more-manageable stepped improvements. Each increment provides an operationally useful capability but not the desired full end capability. No increment is undertaken until its technologies have been demonstrated to be relatively mature. The increments build on each other until the full end capability has been achieved. Yet the risk in each of the smaller and more-modest developmental increments or steps theoretically adds up to a lower overall program risk to reach the same

ultimate capability than a single-step-to-capability program would have had. The assumption is that more-capable variants of a system will be developed over time, in an appropriate sequence. Evolutionary acquisition is applicable to high-technology and software-intensive systems when requirements beyond a core capability can be defined generally but not specifically. A related concept, *spiral development*, implements evolutionary acquisition through an iterative step-by-step assessment of risks and assumptions, the creation of a functioning prototype for proof testing, a periodic evaluation of lessons learned, and a decision at the end of each development cycle about whether to advance to the next phase.

Cost analysis policy assessment is somewhat of a "chicken-or-the-egg" problem

Mark Lorell

Senior political scientist and historian Mark Lorell has been a major contributor to the assessment of Air Force strategies for managing the weapon system acquisition process ever since he came to RAND in 1978. Some of his reports are now standard references in the field, including *Multinational Development of Large Aircraft: The European Experience* and *Cheaper, Faster, Better? Commercial Approaches to Weapons Acquisition*. Today, he focuses on cost growth in major weapon systems, particularly the system development and demonstration period between acquisition Milestones B and C, where significant increases usually begin.

"Cost analysis policy assessment is somewhat of a 'chicken-or-the-egg' problem," Mark says. "Is cost growth the result of an overly optimistic and unrealistic cost estimate with excellent program execution? Or poor program execution starting with a sound and credible cost estimate? Or are other factors important, including some that were unanticipated but justifiable? The purpose of our research is, first, to sort out answers to these questions and then to attack the root causes of cost growth."

Mark has used this historical approach to cost analysis to help guide the Air Force as it seeks to improve the ever-complex acquisition process. Recognizing that the commercial aspects of the problem are not limited to the United States, Mark has also looked at future trends in the European defense industrial base and has offered his expertise to Asian countries. These projects have given Mark the opportunity to learn best acquisition practices abroad that can shed light on such practices at home.

Mark was honored in February 2008 with the RAND President's Award for his significant body of research on strategies and processes for acquiring complex defense systems, in both the United States and other countries. He will continue to lead and contribute to studies that will help the Air Force continuously improve the complex weapon system acquisition process.

The success of the unmanned aircraft system RQ-1/MQ-1 Predator in the war on terrorism led to an increase in production numbers and changes in requirements, which led to large cost increases *and* tremendous benefits for the warfighter.

While evolutionary acquisition seems sensible in theory, there is little experience with actually implementing it. PAF has examined several space acquisition programs using this approach and found mixed results, as reported in *Evolutionary Acquisition: Implementation Challenges for Defense Space Programs*. The iterative nature of the strategy encourages constant changes in requirements, operational concepts, and technical specifications, yet precise cost estimation requires all these factors to remain stable. The more-fluid approach seems to produce an operationally useful system sooner than a traditional approach would. The costs, however, are often higher than originally anticipated, and the approach further complicates already complicated regulatory and oversight requirements. On the other hand, this approach can be a useful tool that offers program managers increased flexibility. Because evolutionary acquisition requires major changes in traditional implementation approaches and may cause budgetary and political problems for program managers, it must be handled carefully.

PAF researchers suggest that, because it is very difficult to know at Milestone B what final program costs will be, an incremental approach makes sense, if carefully implemented. Another approach might be for the government to divide development into several phases and provide contractors with a fixed cost ceiling for each phase. Developers could give a phase their best effort for $X million. When the money runs out, the government would do an assessment and decide whether it wanted to go forward to the next phase for another $X million. That process could iterate as many times as necessary.

Better, more-realistic cost estimates at each phase in the development process would not necessarily save money overall, but they would provide decisionmakers with a better basis for deciding whether to pursue a given program knowing what the true risks and costs were likely to be.

For more information, see

MG-431-AF, *Evolutionary Acquisition: Implementation Challenges for Defense Space Programs*, by Mark A. Lorell, Julia F. Lowell, and Obaid Younossi. Online at http://www.rand.org/pubs/monographs/MG431/

MG-588-AF, *Is Weapon System Cost Growth Increasing? A Quantitative Assessment of Completed and Ongoing Programs*, by Obaid Younossi, Mark V. Arena, Robert S. Leonard, Charles Robert Roll, Jr., Arvind Jain, and Jerry M. Sollinger. Online at http://www.rand.org/pubs/monographs/MG588/

MG-670-AF, *Sources of Weapon System Cost Growth: Analysis of 35 Major Defense Acquisition Programs*, by Joseph G. Bolten, Robert S. Leonard, Mark V. Arena, Obaid Younossi, and Jerry M. Sollinger. Online at http://www.rand.org/pubs/monographs/MG670/

MG-690-AF, *Improving the Cost Estimation of Space Systems: Past Lessons and Future Recommendations*, by Obaid Younossi, Mark A. Lorell, Kevin Brancato, Cynthia R. Cook, Mel Eisman, Bernard Fox, John C. Graser, Yool Kim, Robert S. Leonard, Shari Lawrence Pfleeger, and Jerry M. Sollinger. Online at http://www.rand.org/pubs/monographs/MG690/

Planting the Seeds of Future Leaders

The development of the most senior Air Force leaders begins at the lowest echelon of the officer corps. Yet the task of developing future leaders is not a simple matter of replenishing the number of officers who retire each year with an equal number of junior people. While the most senior positions are filled by people with distinguished flying and leadership experience, the top- and midlevel jobs also require skills in such areas as acquisition, training, and budget planning and execution that are not normally required for a distinguished flying career. Given that the Air Force promotes exclusively from within, this situation is challenging both for those responsible for making promotion decisions and for those charting their own career paths. Junior officers who stand out as good candidates for future leadership in the Air Force or in the joint community have generally distinguished themselves as operators and are not necessarily best prepared for the other positions they must perform along the way to senior leadership positions. From the individual's point of view, the career moves needed to develop skills in such areas as acquisition and training may appear to be detours on the path to advancement, on the assumption that distinguishing themselves as operators and leaders is what will ultimately be valued.

The Air Force has pursued a deliberate force-development initiative over the past ten years to improve the growth of Air Force leaders. PAF has been supporting this effort with a series of research studies designed to identify the skills needed for specific Air Force jobs, to understand how officers acquire these skills during their careers and the best ways to track the skill-acquisition process, and to ensure that the "flow" of officers through a given career field produces an appropriate number of qualified candidates for leadership jobs.

What Skills Are Needed for Leadership Jobs?

PAF laid the groundwork for its force-development research with a study of job requirements for general officer and Senior Executive Service positions. In a survey of general officers and senior executive personnel, researchers discovered that the requirements for senior positions are

Gen Norton A. Schwartz, Air Force Chief of Staff, addresses airmen at Malmstrom Air Force Base, Montana, during a visit for a firsthand look at the intercontinental ballistic missile mission. By the time an officer reaches a senior leadership position, he or she must have a combination of technical knowledge, familiarity with the services other functions provide, and broad leadership and management skills.

The Air Force "Force-Development" Initiative

multilayered. Most jobs have a *primary occupational competency*: prior experience gained in a specific operational or function area (e.g., fighter pilot) or in one of a number of such areas critical to success in the position. Many positions also require a *secondary occupational competency*: prior experience in a second operational or functional area or in one of a number of such areas. For example, a job might call for a person with a primary competency as a fighter pilot but with a secondary competency in political and military affairs. Primary and secondary occupational competencies can be considered provider-level skills: The individual is expected to be able to skillfully perform the functions normally associated with the specific occupations. For example, if the position requires a primary competency as a fighter pilot, the individual must be an experienced and qualified fighter pilot. If the position requires a secondary competency in political and military affairs, the individual must be skilled at performing the tasks normally associated with being a political and military affairs officer. Finally, all jobs require an array of competencies that cross functional and operational areas, such as leadership, management, and enterprise perspective.

A key point is that job requirements must be articulated in terms of these competencies so that people making assignments and promotion decisions can be strategic about current and future needs. Even if a junior officer does not need a certain skill to perform his or her current job, he or she will need to acquire that skill eventually to be able to fill a future leadership position requiring it. The officer therefore needs to obtain the underlying education, training, and experience that will make it possible to demonstrate the desired skill when the time comes.

Opposite: The voice of experience, especially when it comes from the top, and the encouragement of peers are also invaluable in charting a career path. CMSAF Rodney J. McKinley speaks during the Air Force Sergeants Association's annual Professional Airmen's Conference and International Convention August 26, 2008, in San Antonio, Texas.

Below: CMSgt Mike Will, with the 174th Fighter Wing at Hancock Field, New York, greets his family after returning home from a deployment to Southwest Asia in support of Operation Iraqi Freedom. In addition to gaining combat experience, airmen learn many skills during deployments that are necessary for senior leadership.

How Do People Acquire Competencies?

A PAF study of the occupational skills acquired during deployments sheds light on this question and points to the role of varied experiences in skill acquisition. Researchers surveyed officers and enlisted personnel who had recently returned from Prince Sultan Air Base and Eskan Village

The task of developing future leaders is not a simple matter of replenishing the number of officers who retire each year with an equal number of junior people.

(a military housing village) in Saudi Arabia. The two locations were selected because the Air Force had identified deployments as a likely setting for substantial learning and because a large number of Air Force personnel in a wide variety of occupations were deployed at these locations. Respondents were asked to consider a broad range of skills and to rank the environments that were most conducive to learning these skills. Environments included initial and midcareer training, this deployment, other deployments, and settings outside the Air Force.

The survey found that a wide majority of respondents spent some portion of their time during deployment working outside of their occupational specialties. Most identified the Prince Sultan Air Base–Eskan Village deployment as the best environment for learning more than one-third of the skills and competencies listed on the survey, including those having to do with operations, organization, and strategy.

These findings suggest that the Air Force should develop a system for tracking competency attainment in greater detail than it has historically and should incorporate the learning that occurs during deployments and other on-the-job experiences. Such a system would help track which personnel have certain combinations of skills and where gaps in necessary skills still exist.

What Is the Right Flow of Officers Through a Career Field?

The practical application of these insights is a method of analyzing the education, training, and experience requirements for positions (the demand for competencies); the education, training, and experience of personnel (the supply of competencies); and the overall flow of officers through a career field to ensure that the right number of people acquire the right mixes of skills needed to fill the jobs at all levels (what is required to prevent a gap between supply and demand).

PAF has demonstrated its approach with a study of the 13S career field (space and missile operations). The research was a response to Air Force Space Command's concern about the health of the 13S career field,

which requires officers to be familiar with both missile and satellite systems. To help clarify and improve the process of developing 13S officers, PAF implemented a four-step supply-and-demand approach:

1. Identify the backgrounds needed for a variety of jobs. Senior 13S officers rated the importance of 70 specific backgrounds (defined in terms of education, training, and experience) for satisfactorily performing 1,100 jobs authorized at the ranks of major, lieutenant colonel, and colonel.
2. Assess the backgrounds today's officers already possess and the career paths they have followed. PAF researchers analyzed personnel records for more than 3,000 space officers from 1975 to 2001.
3. Measure the gaps between supply and demand. Considered as a whole, the officers in each rank had most of the backgrounds considered important for their jobs—for example, a technical degree; experience in the various operational missions areas, both as instructors and as commanders; and experience in current operations, logistics, and plans and programs. Too few had experience in the areas of contingency and war planning; in safety, intelligence, or acquisition; or in a numbered air force. More significantly, shortages were somewhat larger when backgrounds were considered in combination, representing the mixture of primary and secondary competencies that previous PAF research established to be so important. Most significantly, gaps between the experience needed and what officers had were widest at the level of detail of individual people in specific positions, where they matter most. For about 90 percent of the jobs that needed an officer with certain experience, the incumbent lacked one or more of the needed types of experience.
4. Model potential development and utilization patterns to see whether a better flow could match supply more closely with demand. PAF developed an optimization model to find ways to flow officers through jobs in such a way that 99.5 percent of jobs would be filled by people with the necessary backgrounds.

While it would be impossible in practice to manage officer flows as precisely as the model proposes, these results demonstrate the potential for greatly improving the match between the competencies required and the competencies an individual officer brings to a specific position in a given career field and the potential for stabilizing and sustaining an optimal movement of officers through the system.

Job requirements must be articulated in terms of these competencies so that people making assignments and promotion decisions can be strategic about current and future needs.

Moving Forward

PAF has been using the same approach to optimize force development in other Air Force career fields, both at the senior levels, including general officer and Senior Executive Service positions, and, more recently, among the enlisted force, including the development of chief master sergeants.

No one knows for certain which newly commissioned Air Force officers will become senior leaders or which enlisted personnel will become top-ranking chief master sergeants. The force development initiative is about planting enough seeds in the right soil to ensure an abundant yield of outstanding leaders year after year.

For more information, see

DB-435-AF, *The Role of Deployments in Competency Development: Experience from Prince Sultan Air Base and Eskan Village in Saudi Arabia*, by Laura Werber Castaneda, Lawrence M. Hanser, and Constance H. Davis. Online at http://www.rand.org/pubs/documented_briefings/DB435/

MG-382-AF, *Improving the Development and Utilization of Air Force Space and Missile Officers*, by Georges Vernez, S. Craig Moore, Steven Martino, and Jeffrey Yuen. Online at http://www.rand.org/pubs/monographs/MG382/

MG-545-AF, *Advancing the U.S. Air Force's Force-Development Initiative*, by S. Craig Moore and Marygail K. Brauner. Online at http://www.rand.org/pubs/monographs/MG545/

TR-175-AF, *Integrated Planning for the Air Force Senior Leader Workforce: Background and Methods*, by Albert A. Robbert, Steve Drezner, John E. Boon, Jr., Lawrence M. Hanser, S. Craig Moore, Lynn M. Scott, and Herbert J. Shukiar. Online at http://www.rand.org/pubs/technical_reports/TR175/

Lawrence Hanser

Lawrence Hanser has been working with the U.S. military on force development issues since the early 1980s. Today, he is a senior behavioral scientist at RAND, where he plays a leading role in PAF's efforts to help the Air Force develop better matches between senior leaders and the jobs they perform.

Before joining RAND, Larry earned a Ph.D. in industrial and organizational psychology; taught college-level industrial-organizational psychology, statistics, and psychometrics (the field of measuring knowledge, abilities, and personality traits); and worked as a civilian scientist for the U.S. Army Research Institute for the Behavioral and Social Sciences, where he helped design and later headed a large personnel-selection project focused on identifying the competencies required for success in Army occupations and how best to select individuals to serve in specific occupations. From 2005 to 2008, he served as Associate Program Director for PAF's Manpower, Personnel, and Training Program.

"Leaders in every organization say that people are their most important asset, but when it comes down to it, they want to talk about something else they view as more interesting," says Larry. "But personnel issues are critical. Does the organization have enough people with the appropriate skills to do what it needs to do?"

Larry's approach to answering this question, reflected in the ongoing work he and his colleagues have been doing for the Air Force since the late 1990s, has broad application to military and civil organizations. Since working at RAND, he has chaired an expert panel sponsored by the Office of the Secretary of Defense to review the Department of Defense Human Capital Strategy. He has also brought his expertise in industrial-organizational psychology to the analysis of issues as diverse as allowing gays and lesbians to serve openly in the U.S. military, firearms training in the New York City Police Department, and the improvement of secondary school education. Hanser himself plays an active role in mentoring Air Force fellows, who spend a year at RAND working on PAF research as part of their leadership development. Along with Mike Kennedy, he ensures that fellows are quickly and usefully integrated into PAF's research program.

Personnel issues are critical. Does the organization have enough people with the appropriate skills to do what it needs to do?

In all his work, Larry has sought to show how organizations can shape their futures for the better by taking a strategic approach to development, starting with the lowest echelons of training, education, and work experience. "We certainly have ideas about how to plan for the future," he says. "The most important thing is to remain open-minded and to make choices now that broaden rather than narrow the range of possible future choices."

Going for the Gold

PAF's Quality Assurance Process

Cynthia Cook

RAND has overarching standards for quality that articulate its analytic aspirations.

At RAND, the words *quality* and *objectivity* have special meaning: They represent the twin goals researchers seek to achieve in all their work. This is not something left to chance, however. RAND has overarching standards for quality that articulate its analytic aspirations. Developed over the course of 60 years, these standards seek to ensure that RAND's research is technically sound and free from bias. They include the following:

- The research problem should be well formulated, and the research approach should be carefully designed and executed.
- The data and assumptions should be sound.
- The research should demonstrate understanding of previous related studies and should be communicated in an accurate and understandable way.
- The findings should be useful—i.e., they should advance knowledge and be relevant to the needs of the client and other stakeholders.
- The entire research enterprise should be objective, independent, and balanced.

Each division within RAND has rigorous quality assurance processes designed to produce research that conforms to these standards. Within RAND Project AIR FORCE, coordinating this process is the responsibility of Cynthia Cook, who serves in a dual role as PAF's associate director and its quality assurance manager.

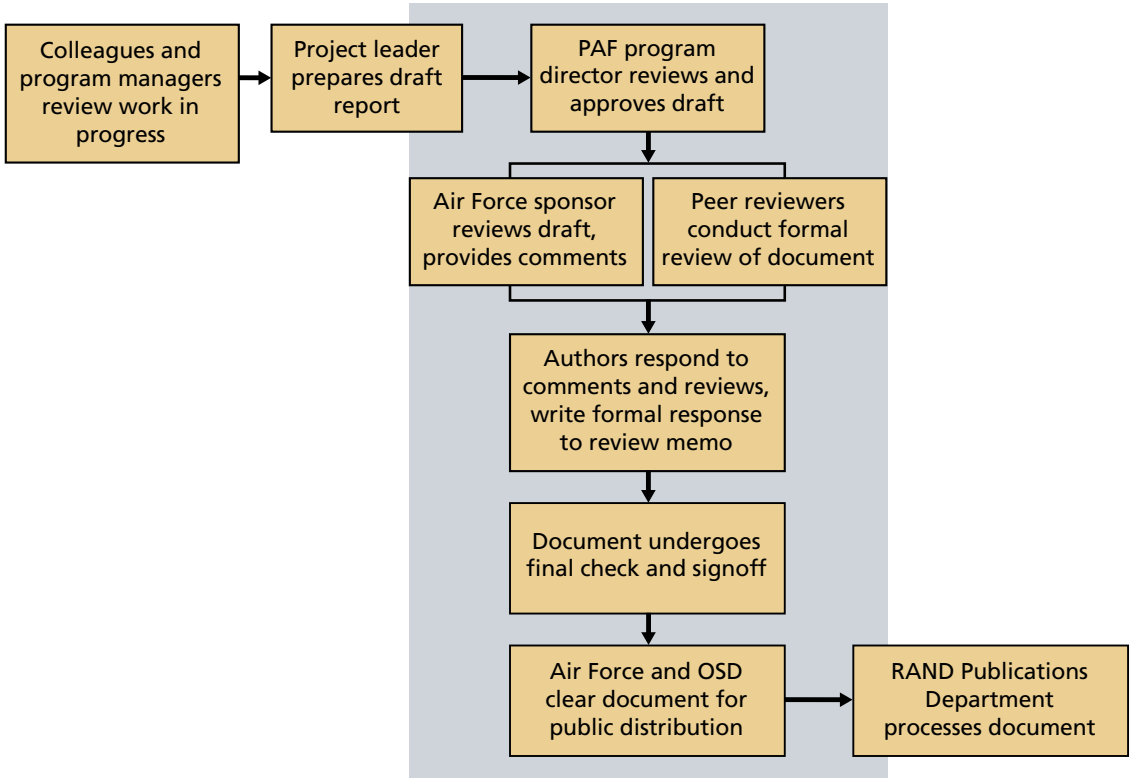
Quality Assurance Is a Multistep Process

PAF aims to design quality into every stage of the research process. This begins during the project planning phase, when the research sponsor, the program director, and the project leader work together to develop a project description that defines a problem the Air Force is facing and an approach to solving it. Another important step is to appropriately staff and fund the project. In assembling the research team, it is crucial to recruit a research team with the right mix of skills for the specific project and to ensure that this team receives adequate resources to complete its assigned tasks.

The formal quality assurance process begins with work-in-progress seminars, in which project teams brief their program directors and their PAF colleagues on their research objectives, study approach, and interim findings. In return, the team receives feedback at a stage in the process when meaningful substantive adjustments can be made without adding delays or costs.

During the course of a study, a PAF research team produces a variety of deliverables to share preliminary results and to elicit client guidance. Program directors review briefings and selected written communications, and PAF's director often previews briefings that will be presented to Air Force general officers or other senior military and government decisionmakers.

Figure 1: As a key part of the quality assurance process, PAF's final reports undergo intensive review to ensure that they meet or exceed RAND's standards for quality and objectivity.



Part of RAND's mission is to make its publications as widely available to the public as possible. As shown in Figure 1, draft versions of documents that describe final research results are subjected to very careful scrutiny before formal publication. Cynthia manages the formal peer-review process, which provides an unbiased evaluation of the quality of all published products, including those with limited distribution because of classification or other restrictions.

The formal peer-review process provides an unbiased evaluation of the quality of all published products.

The process begins when Cynthia examines the document to determine an appropriate review strategy. Generally, she chooses a minimum of two reviewers. One is usually a RAND researcher, and one is an expert from outside RAND. If the subject matter is so specialized that an appropriate external reviewer cannot be found, a second RAND reviewer from outside PAF fulfills that function. However, some documents are so complex and contain such a broad range of findings that two reviewers simply cannot be expected to assume responsibility for evaluating every element of the content. For example, a report that focuses on several countries or regions may require experts on each locality to review individual chapters, along with one or more additional reviewers to give an overall evaluation. Cynthia provides the reviewers with careful guidance about what to consider when they write their reviews, along with a description of RAND's quality assurance standards.

Once the authors receive the reviewers' comments, they carefully consider each point that has been raised. They must write formal responses to all review memos and indicate how each concern has been addressed. They also share the revised version of the document. Authors send copies of every review and every response to all reviewers, who must ultimately approve the document as a whole and not merely judge whether the authors responded acceptably to their individual concerns. Reviewers who are not satisfied with the results can request further changes. Occasionally, the review process may lead to a decision not to publish; the primary reason would be that reviewers have identified difficult-to-resolve problems that undermine the document's potential contribution to the policy debate.

Once the approval of the reviewers is secured, the document goes through a final program-level review and is then sent to Cynthia, who must sign off as quality assurance manager. She checks the reviews and responses to make sure the authors did, in fact, attend to all the issues. She then rereads the document to ensure that the necessary changes were indeed made. Cynthia brings a PAF-wide perspective to these tasks, going beyond program-level expertise to check for tone and to bring insights she gains from reviewing the complete portfolio of PAF's research.

A Dual Perspective on Quality Assurance

Cynthia has a full appreciation of the quality assurance process not only because she manages it but also because she is a researcher herself. "Staying involved in research gives me renewed appreciation for the importance of quality assurance. I can also use my own work as a test for the efficiency of the process. To maintain objectivity, the unit director takes over the quality assurance function for any project I'm involved in."

In her eleven years at RAND, Cynthia has compiled a long list of projects, most of them in the broad area of resource management. Recently, she worked with colleague Michael Boito to examine the Air Force's increasing use of contractor logistics support during the operating and support phases of a weapon system's life cycle. Several of their recommendations centered on ways to help the Air Force retain flexibility in its choices for logistics services and to centralize and strengthen the data collection and analysis capabilities of its logistics community. Cynthia and Mike followed that study with a cost-benefit analysis that compared the use of prime contractors to manage the sustainment of the F-22 fighter aircraft with the use of an "organic" sustainment capability within the Air Force. Currently, Cynthia has teamed with John Ausink to identify the ways in which participation in joint taskings affects the Air Force's combat support capability.

Cynthia received her doctorate in sociology from Harvard, where she focused on the study of organizations. "While I was writing my dissertation, I worked as a researcher at the Lean Aerospace Initiative at the Massachusetts Institute of Technology. That experience greatly expanded my understanding of aerospace manufacturing processes. Since then, process improvement has become one of my ongoing interests. I have tried to apply that knowledge in my research projects. Now I can also do it as PAF's quality assurance coordinator by helping to develop and manage a system that turns out the highest quality documents we can produce, but with the lowest possible bureaucratic burden."

Above: Employees at Lockheed Martin's F-22 Raptor production facility attach a tail fin to the body of Raptor 4087. The aircraft, the first to bear the "AK" tail flash, is destined for Elmendorf Air Force Base, Alaska. Cynthia Cook's recent work has examined the growing use of contractors for logistics support throughout a major weapon system's life cycle.

Opposite: Cynthia's research has helped the Air Force plan for sustainment surge, the increase in requests to repair weapon systems and components to meet the operational demands of wartime or contingency operations. Here, Staff Sgt. Albert Zaletel works on an F-16 Fighting Falcon at Hill Air Force Base, Utah.

For more information, see

RAND's Web site: http://www.rand.org/standards/
This site provides a detailed description of RAND's quality-assurance goals and process.

MG-372-AF, *Rethinking How the Air Force Views Sustainment Surge*, by Cynthia R. Cook, John A. Ausink, and Charles Robert Roll, Jr. Online at http://www.rand.org/pubs/monographs/MG372/

MG-779-AF, *Contractor Logistics Support in the U.S. Air Force*, by Michael Boito, Cynthia R. Cook, and John C. Graser, forthcoming.

Sharp Focus, Fast Reflexes

In an age when small, highly mobile groups of terrorists and insurgents can inflict potentially catastrophic harm on the United States and its allies, U.S. armed forces must have sharp focus and even sharper responses. It is no accident that today's unmanned aerial systems have such names as "Predator" and "Global Hawk," invoking images of birds of prey that can fly very high, see with extraordinary keenness, and attack with lightning speed.

New Capabilities and Old Models

Advanced sensors have made it technically possible to rapidly detect, identify, and track targets of interest in very remote environments, such as oceans and deserts, even at night and in bad weather. But these capabilities are new enough that the methods of planning, executing, and assessing intelligence, surveillance, and reconnaissance (ISR) missions have not caught up with what is possible—and needed—against fleeting targets.

One reason is that today's terrorist, insurgent, and criminal threats are more agile than the large, conventional forces that were the focus of planning during the Cold War. Older ISR models assumed relatively long, predictable scenarios, such as conventional armies massing for attack in known locations. ISR collections were planned in 24-hour blocks, and the priorities were clear over the course of a conflict. These methods are bound to be ineffective against today's enemies, who may attempt lower-profile operations, such as smuggling a dirty bomb into a U.S. harbor on a yacht. The United States must be able to adapt its ISR collections in real time in response to new detections and identifications—whether that means tracking a detected vehicle; striking a high-value, time-sensitive target; or prompting law enforcement authorities to intercept a suspect.

Compounding this challenge is the fact that ISR resources are still scarce. Intelligence officers must often decide between going after emerging collection opportunities or sticking with the daily collection plan, yet they currently lack an easy means of trading off the costs and benefits of each. How important is a given collection in the context of the commander's campaign goals? Which goals may go unmet if resources are redirected to the new collection opportunity?

Global Hawk and other unmanned aircraft systems can provide high-quality, real-time imagery to battlefield commanders via worldwide satellite communication links. This technology can greatly enhance ISR operations, but operators and planners need new tools and approaches to make best use of the capability.

Planning, Executing, and Assessing Intelligence, Surveillance, and Reconnaissance Operations in Dynamic Environments

Global Hawk will soon replace the aging U-2 (shown here) to provide long-endurance, broad-area surveillance over the Pacific Ocean.

A New Set of Models

In recent years, PAF has developed a set of models to improve the planning, execution, and assessment of ISR assets in the context of today's technological and operational realities. This stream of work consists of three suggested approaches that should help the Air Force ensure that, even as potential threats become more agile and elusive, it makes the best use of available sensor technology and limited intelligence assets.

Improving ISR Collection Planning and Execution

PAF suggests that the Air Force enhance its planning for daily intelligence collection by adopting a strategies-to-tasks and utility-based framework. As shown in Figure 2, the commander's top-level objectives are analyzed, then organized into operational objectives and tasks and the specific ISR collections that support them. For example, the overall goal of enabling offensive operations entails the goal of gaining air superiority, which in turn requires blue forces to neutralize surface-to-air missiles. ISR assets can support this task by imaging suspected missile launch sites. The number in each box represents the relative utility of each objective, task, or collection—how important is it in supporting the objective or the task above it relative to the other branches of the hierarchy? Based on these numbers, each collection has a *utility value* that establishes its place on the priority list. The result is a quantitative measure of how each planned collection supports the commander's objectives. Intelligence officers can use this framework in real time to assess the relative utility of an ad hoc collection opportunity and to change priorities as appropriate.

Analyzing the Costs and Benefits of ISR Collection Strategies

Some ISR assets and operational concepts will be better for carrying out collection tasks than others, depending on the operational environment and

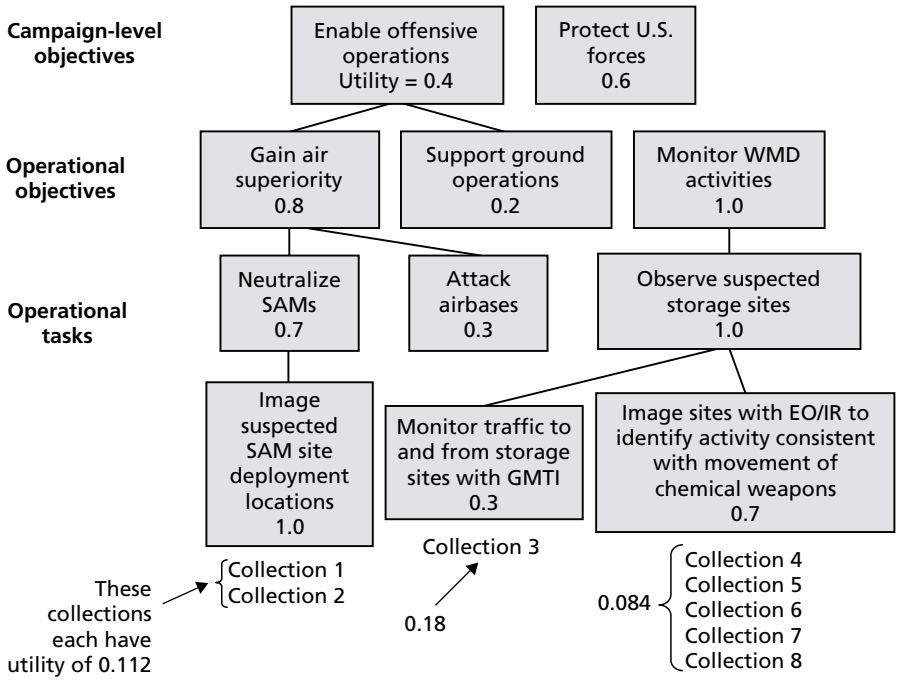
enemy operational concepts. PAF developed a suite of models to analyze the process of building collection "decks" (i.e., planned collections) and their execution in a simulated environment that reflects today's dynamic scenarios. Analysts can use this model to consider the trade-offs between various platforms, including manned and unmanned aircraft; different sensor options and methods of employing them; and alternative flight patterns that may be suitable for a given mission. The model has a powerful diagnostic capability that helps analysts understand why one configuration may have performed better or worse than another. These insights are particularly useful as the Air Force relies more heavily on innovative technologies, such as unmanned vehicles with advanced sensor packages, to monitor parts of the world that were previously very difficult to observe, such as the ocean surface.

PAF has developed a set of models to improve the planning, execution, and assessment of ISR assets in the context of today's technological and operational realities.

Improving the ISR Assessment Process

To ensure efficient use of limited intelligence assets, an end-to-end assessment process is needed to monitor and evaluate daily operations. To date, the majority of ISR assessments have focused on statistics from the tactical level (e.g., the percentage of planned images collected), but these data do not indicate how well the ISR system satisfied the commander's objectives. Adopting a strategies-to-tasks framework for collection planning at the joint task force level will close this gap. Joint task force and component commanders should mandate feedback on ISR performance from all requesters and users of ISR-generated intelligence, and doctrine and manuals should be updated accordingly.

Figure 2: Calculation of Notional Target Utility Values



Modeling and simulation can achieve a remarkable degree of fidelity if you remain focused on the physical dimension of what you're trying to accomplish.

Sherrill Lingel

For over a decade, Sherrill Lingel has been one of the leaders of PAF's ongoing research on ISR planning, execution, and assessment. She and her fellow researchers have been working with sponsors in Pacific Air Forces, Air Combat Command, and other commands to develop and expand the models that make analysis of today's ISR realities possible.

"The Air Force has made a long-term investment in this research, and it is paying off," she says. "We have seen this work go from a set of fundamental modeling questions to a suite of tools that we can use to help different commands think through real ISR challenges and investment strategies."

Sherrill has been working on engineering and modeling problems for her entire career. At the University of Washington in Seattle, she earned a master's degree in aeronautical engineering and a doctorate in civil and environmental engineering, where she worked on modeling and analysis of fluid dynamics in both air and water.

Today at RAND, she applies her skills in engineering and modeling to studying Air Force issues involving ISR, the employment of unmanned aircraft systems, aircraft survivability, and others.

The common thread is an interest in the physical realities that structure such problems and make it possible to model and experiment with potential solutions. "Modeling and simulation can achieve a remarkable degree of fidelity if you remain focused on the physical dimension of what you're trying to accomplish," says Sherrill. "There is a lot of theory involved, but your model has to be grounded in the hard science that lies underneath."

In recognition of her work on ISR modeling, Sherrill received a RAND President's Award in 2008, which grants 20 days of coverage to pursue research on any topic. She plans to use the time to extend her work into the area of space-based ISR.

U.S. ISR assets must be able to detect, classify, and track small, fast-moving vessels, such as this drug-smuggling boat (bottom), and to cue local authorities, such as the Coast Guard (top).

A Resource for Air Force Major Commands

PAF's modeling framework has already helped some Air Force commands think through decisions about the acquisition and employment of ISR platforms and sensor equipment. Pacific Air Forces provided impetus for PAF's research in FY 2005 by asking for a tool to show its commander the costs and benefits of alternative collection strategies. In subsequent work, researchers showed that, with certain feasible sensor upgrades, the Global Hawks that Pacific Air Forces will receive in FY 2009 can provide "eyes and ears" for counterinsurgency, antipiracy, and other missions that are typically difficult to conduct at sea. Since then, PAF has expanded the analysis to include Global Hawk's potential maritime surveillance roles across all commands and the potential roles for both land-based and airborne ISR platforms for U.S. Air Forces in Europe and in the newly created Africa Command. Researchers continue to expand the models to incorporate additional platforms, sensor designs, operational concepts, and environments. This line of research will continue to help the Air Force keep ISR capabilities at the leading edge of what is possible and needed against threats that are ever more elusive.

For more information, see

TR-459-AF, *Methodology for Improving the Planning, Execution, and Assessment of Intelligence, Surveillance, and Reconnaissance Operations*, by Sherrill Lingel, Carl Rhodes, Amado Cordova, Jeff Hagen, Joel Kvitky, and Lance Menthe. Online at http://www.rand.org/pubs/technical_reports/TR459/

Getting More from the Total Force

The U.S. Air Force is getting smaller. By the end of FY 2009, mandated personnel reductions will eliminate up to 24,000 positions, most of them in the active-duty component. The number of aircraft in the inventory is also declining: There were nearly 1,700 fighter aircraft in the total force in 1998 but fewer than 1,400 in 2008. For the most part, this downsizing is not a cause for concern about the service's ability to perform its mission. Across-the-board technological advances, particularly in the development of sophisticated communications systems, increasingly lethal weaponry, and a highly agile combat support organization, have made the Air Force more capable than ever before. However, there is already a chronic shortage of active-duty pilots because their skills and knowledge are also required in nonflying positions elsewhere within the Air Force. If compensatory actions are not taken, the infrastructure reductions described above will increase this deficit.

Air National Guard Resources May Help Improve the Efficiency of Flying Operations

The Air National Guard (ANG) will not experience the same kinds of manpower losses as the active Air Force. It will retain a cadre of highly experienced pilots and maintenance personnel. Moreover, recent realignments and closures of air bases mean that large numbers of aircraft will remain in ANG units. This puts the ANG in a very favorable position to support increased flying operations to help maintain the skills of active-duty Air Force pilots.

The Air Force has a long history of linking—or *associating*—active units with Air Force Reserve or ANG units to conduct strategic airlift and tanker operations. The concept of associate units was reinvigorated in 1998 with the establishment of the Total Force Integration initiative, which, as its name indicates, seeks to combine these three components into a smoothly operating and streamlined totality.

Previous PAF research showed that ANG F-16 units were able to generate peacetime training sorties and meet the required standards for aircraft maintenance with a workforce that was about one-third the size of its active-duty counterpart. In fact, the number of flying hours generated per maintainer is more than twice as high in an ANG unit. With

Technicians from the 180th Fighter Wing of the Ohio Air National Guard remove the engine from an F-16 during their deployment to Qatar.

Using the Air National Guard to Help Trim Force Size Without Losing Pilot Power

that in mind, senior leaders on the Air Staff and in the ANG asked PAF to account for this striking difference in productivity and to develop staffing options for *active associate units* that would provide aircraft maintenance to effectively support Total Force Integration objectives. These new units would be ANG or Air Force Reserve units to which active-duty personnel would be permanently assigned. Instead of adhering to traditional Air Force practice, which is for the active component to take primary responsibility for its own weapon systems, the maintenance of these systems would now fall to the reserves.

Greater Experience and Stability in the ANG Workforce Make Its Aircraft Maintenance Units More Productive Than Their Active-Duty Counterparts

PAF researchers examined key factors that may account for the variation in productivity levels. They did not identify significant differences between wartime and peacetime sortie-production requirements, mainly because much of the increased tempo in wartime is managed by having technicians spend more hours on the job. However, in several other areas, they found that certain demands on active-duty maintenance personnel drew them away from their primary tasks and reduced the amount of time they could actually devote to maintaining aircraft. These findings are summarized below.

Out-of-Hide Duties

Out-of-hide slots are positions within a unit that a maintenance technician would normally fill but that are not recognized in the Air Force's manpower allotment model. The active component treats these positions as full-time assignments, and PAF estimates that approximately 5 percent of its workforce is performing out-of-hide duties at any given time (see Figure 3). However, the ANG absorbs the additional work into its regular schedule, so effectiveness suffers little.

On-the-Job Training Requirements

A substantial part of the workforce in an active-component maintenance unit consists of junior-level personnel who require further instruction. Past analyses have estimated that the productivity level of trainers averages 15 percent lower because of the time they spend training inexperienced personnel. Moreover, on average, a trainee is only 40 percent as effective as a fully trained, experienced individual. The ANG does not have similar problems because it hires people into its workforce who are able to do the work immediately. Any training that may be needed to develop new skills or refine existing ones is conducted on once-a-month drill weekends or during the two-week annual training period. Thus, trainer-trainee productivity effects are negligible in the ANG.

Supervisory Responsibilities

In the active component, maintenance technicians who attain the rank of master sergeant become full-time managers and no longer perform hands-on duties. The ANG uses almost the entire full-time technician workforce, including the supervisors, in a hands-on capacity.

Shift-Scheduling Practices

The active component strives to keep the maximum number of aircraft fully mission capable at all times. This requires the operation of two maintenance shifts, and some units even have a small service crew on a third shift. Because of uncertainties about the type of labor that will be needed, how much, and when, managers must duplicate certain types of manpower on each shift. This reduces unit effectiveness. On the other hand, most ANG units operate only a single shift to support peacetime training sorties and repair "to the flying schedule." That is, instead of fixing everything as quickly as possible, they focus on ensuring that sufficient flyable aircraft are available to support the next period's flying schedule and perform other maintenance as time permits.

Personnel Stability and Cross-Training

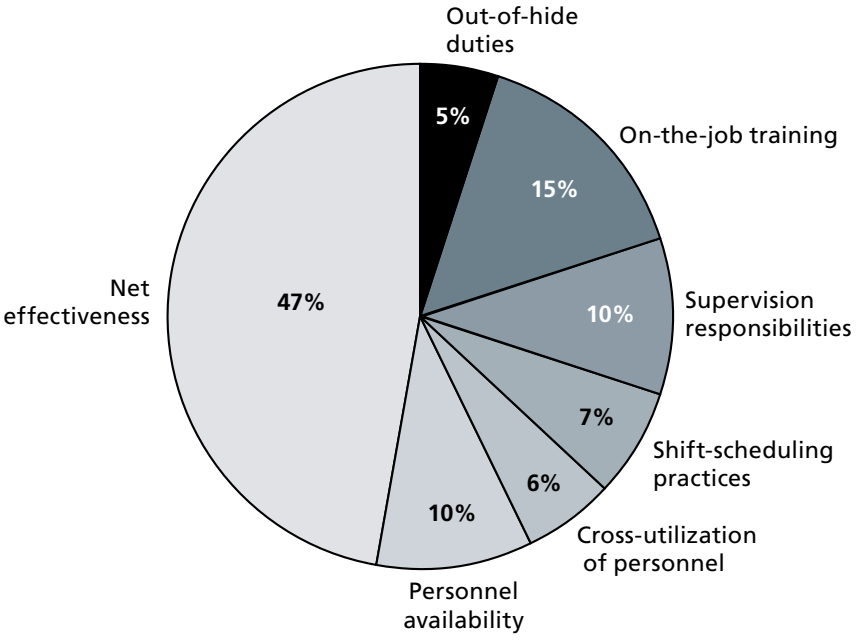
Amount of experience and stability in work assignments affect worker productivity. Besides having an average of only seven years of experience (including time spent in training activities), active-component maintainers generally move to a new assignment every three years. Even if they work on the same airframe or perform the same type of repair, there is a certain amount of turbulence each time new teams are formed. On the other hand, ANG teams are relatively stable. The average full-time technician has over 15 years' experience and has been at one location most of his or her career. These maintainers are also cross-trained to assist in more than one shop, so they can better adapt to fluctuations in type and degree of workload.

Personnel Availability

All active-component personnel must complete ancillary training, maintain proficiency training, and perform other military duties (e.g., honor guards), all of which limit their ability to do hands-on maintenance. Conservatively,

The Air Force has a long history of linking—or associating—active units with Air Force Reserve or ANG units to conduct strategic airlift and tanker operations.

Figure 3: Competing Demands on the Time of Active-Duty Maintenance Personnel Reduce Overall Unit Effectiveness to About 47 Percent



John Drew

By the time John Drew was officially employed by RAND in 2003, he had already been working with researchers from PAF's Resource Management program for six years. That connection was first made in 1997, when John was superintendent of the Aircraft Maintenance and Munitions Division at the Air Force Logistics Management Agency (AFLMA) in Alabama. The U.S. Air Force was just beginning to develop the Expeditionary Air Force concept (now called the Air and Space Expeditionary Force), which centered on the ability to quickly project and employ combat forces worldwide and to sustain operations indefinitely. The success of this enterprise required an equally visionary approach to logistical support. AFLMA and PAF formed a strategic partnership to address the emerging challenges and, over several years, designed a global system now known as Agile Combat Support. John was AFLMA's point person for this task, and he worked with a PAF research team led by Bob Tripp, who had also had an Air Force career.

John brought along a wealth of logistics experience when he came to RAND. Among his earlier assignments, he had been a flight-maintenance chief and a sortie-generation flight superintendent at Moody Air Force Base in Georgia. In late September 2001, he had been called to the Pentagon to help set up and manage the Air Force's global combat support functions for Operation Enduring Freedom, the U.S. response to the 9/11 attacks. "I was fortunate that, during my time in the Air Force, I was given an opportunity to start new organizations," he says. "You learn a lot more when you get to build something new. It prepared me to think beyond what is and focus on what could be."

Some of our best insights come from walking around air bases, talking to people at all levels, and watching them do their work.

John has been able to teach the PAF team a lot about the nuts and bolts of logistics. But he has learned a lot from them, too. "The hardest part of doing research at RAND is structuring the problem. Sometimes we find we're looking at symptoms and not the real issues. So, first, we have to identify the real issues, and then we have to make sure that they can be illuminated by analysis. We know that our Air Force sponsors aren't interested in academic exercises. They also aren't interested in having us tell them 'the right answer.' What they need to know are the pros and cons of a range of options, and they'll make the decisions."

John considers the team approach essential in bringing a research project to a successful conclusion. "We brainstorm, we storyboard, and we collaborate on briefings and reports." The complementary skill sets of the team members are crucial. "For example, Bob has a long experience with the Air Force, with logistics and system design. He brings a system perspective. Our colleague Kristin Lynch can turn long, complicated discussions into a series of concise statements that exactly capture the key points, and she has a keen eye for detail. I'm the operational guy. I figure out what the tasks are, what data we can use, and where we can get it."

Time spent in the field is another important dimension in this type of research. "Some of our best insights come from walking around air bases, talking to people at all levels, and watching them do their work. Bob and I spent decades in the Air Force. We speak the language, and we've walked in their shoes. We interact continuously with our research sponsors. Sharing our ideas before the analysis is entirely completed can be scary sometimes. But Bob has taught me that you have to be willing to have the conversation, open yourself up and talk about the direction you're headed, and give the sponsor a chance to comment. Otherwise, you run the risk of marching down the road to do something that's completely wrong, or do something that's analytically correct but unhelpful. That's not to say that the Air Force shapes or drives the analysis. That's an objective process. We're always trying to come up with new and innovative ideas, but we need to know where the edges are. As Bob says, we should be out there pushing on the balloon all the time. The Air Force is strong. If we go too far, they'll push back."

these tasks can take up two days per month per maintainer. ANG personnel do not have similar requirements. In fact, their training time is scheduled separately, via training assemblies, drill weekends, and civil service leave, actually increasing their availability when they are on the job. PAF calculations show that a typical active-component unit achieves only 47 percent of its maximum potential effectiveness per person assigned, while a typical ANG unit achieves about 90 percent.

Active Associate Units Can Be Staffed to Support a Flying Schedule That Satisfies Pilot Training Requirements

As part of this study, PAF developed a model that simulates a daily flying program that might be typical in an active associate unit. The model takes into account such elements as number of flying days per week, number and timing of sorties each day, historical break rates, repair times, and total aircraft inventory. The model simulates several weeks of flying to study the supportability of the scenario. As aircraft return from their sorties, the model randomly "breaks" them in a way that matches historical rates and then tracks the time needed to repair them. If enough aircraft can be repaired during a single shift to meet the proposed flying schedule, the sequence continues. If that number is insufficient, the model adds a second shift and adjusts repair times accordingly.

The process of evaluating the staffing needs of an active associate unit must also take into account the number of active-duty pilots who have been assigned to an ANG base, which increases the sortie requirements, as well as the number of aircraft that have been transferred as a result of base closures, which impose an additional maintenance burden. PAF's research indicates that, if an ANG unit were to move from its relatively low current sortie rate to the higher utilization rates implied in the Total Force Integration initiative, it would probably have to add another shift of maintenance workers.

The Air Force has two principal candidate ways to meet this need:

- Establish a cadre of active-duty maintainers at the ANG unit to provide the necessary capability. The cadre might include inexperienced personnel, and the active associate unit could then be seen as providing training not only to pilots but also to maintenance staff.
- Convert some of the traditional ANG slots to full-time technician slots and hire new, experienced people to fill them. This would seem to be the easier of the two paths because it would not increase either active- or reserve-component authorizations. Pursuing this strategy would mean increasing the budget for the reserve component units. However, dividing the substantial on-the-job training burden between the active and reserve components may be well worth considering.

The methodological approach developed for this research is not only relevant to the problem of staffing an active associate unit. It can also be used to evaluate productivity differences between the active component and the ANG more generally. This type of analysis could lead to useful insights about ways to improve the efficiency and effectiveness of Air Force operations in areas other than maintenance.

For more information, see

MG-611-AF, *Options for Meeting the Maintenance Demands of Active Associate Flying Units*, by John G. Drew, Kristin F. Lynch, James M. Masters, Robert S. Tripp, and Charles Robert Roll, Jr. Online at http://www.rand.org/pubs/monographs/MG611/

Controlling Crises

Understanding How Military Conflicts Escalate and How the United States Can Keep Them in Bounds

Perhaps the greatest fear during the Cold War—for everyone from civilians to political and military leaders—was that the United States and the Soviet Union would become engaged in a conflict that would escalate out of control, launching both countries and their allies across the threshold of the unthinkable. The 1962 Cuban Missile Crisis was a harrowing demonstration of what could go wrong—and how quickly.

The United States no longer faces a single peer adversary armed with nuclear weapons, but the danger of today's threats amplifying to dire proportions is still real. Relations with large nuclear powers, such as China, require careful management to ensure that any tensions that may erupt do not get out of control. The recent or potential emergence of new nuclear-armed powers, such as North Korea and Iran, increases the risk of crises erupting into regional conflicts and challenges efforts to manage that risk should the United States choose to intervene. Finally, irregular warfare with global jihadists, insurgents, and other nonstate actors can burgeon into lengthy and costly conflicts, despite U.S. conventional superiority.

If anything, the chances of escalation are greater today than during the Cold War because potential adversaries are less stable than the Soviet Union was and because U.S. security analysts and policymakers no longer focus on escalation management—the knowledge and strategy concerned with keeping limited conflicts within bounds or effectively pushing the boundaries when it is in the United States' interest to do so. Understanding escalation is particularly important to the U.S. Air Force because of its unique ability to strike deep within enemy territory and its doctrinal emphasis on rapid strategic attack to achieve shock, paralysis, and escalation dominance.

Understanding the Mechanisms Behind Escalation

Escalation can rarely, if ever, be *controlled*, but by understanding the motives and mechanisms that drive it, military and political leaders can anticipate, recognize, and manage the risks of a confrontation getting out of control. There are three major mechanisms.

Some adversaries have sought to offset U.S. conventional superiority by escalating a conflict beyond what the U.S. public and leaders are willing to endure, as when Lebanese terrorists bombed the U.S. embassy and Marine barracks in Beirut in 1983. The attacks resulted in the withdrawal of U.S. forces from Lebanon.

The Soviet Union crossed a major threshold by placing offensive missiles in Cuba in 1962. The United States used diplomatic channels to prevent the crisis from escalating into a potential nuclear war.

Deliberate Escalation

Deliberate escalation involves intentionally increasing the scope or intensity of an operation to gain advantage or avoid defeat. Classic examples include Germany's use of submarine and gas warfare to break the deadlock in World War I and its bombardment of England with V-1 and V-2 rockets during World War II. Deterrence is the best strategy to counter this kind of threat: One must convince the enemy that the cost of escalation will outweigh the benefits, either because these actions will incur punishment or because the opponent can counter these actions sufficiently to deny their benefits.

Inadvertent Escalation

A combatant who takes a deliberate action but does not perceive it to be escalatory yet whose enemy does perceive it that way has inadvertently caused escalation. This is possible because every combatant has a set of escalation thresholds—lines which, if crossed, will take the conflict to a more serious level. Some are obvious, such as attacks on the homeland, deliberate strikes on civilians, or use of prohibited weapons. Others are not always clear. For example, the United Nations forces' drive into North Korea in 1950 was not expected to provoke an intervention from China, which for its part perceived the act as unacceptably threatening. The result was two additional years of attrition warfare on the peninsula. The best strategy for managing this kind of risk is for each side to make its own thresholds known and to collect intelligence to determine the enemy's thresholds. In the first Gulf War, for example, the United States warned Saddam Hussein against using chemical weapons, thus clarifying a U.S. threshold and deterring escalation by carrying an implicit threat of retribution. The strategy was successful: Saddam refrained from using his supply of chemical weapons against U.S. forces during that conflict.

Accidental Escalation

Accidental escalation occurs when operators make mistakes, such as bombing the wrong targets or straying across geographical boundaries, or when leaders fail to set appropriate rules of engagement or to maintain adequate discipline over their forces. One of the most significant examples occurred in 1940, when a small force of German bombers accidentally attacked London. The Royal Air Force responded by launching its first raid against Berlin on the following night, which, in turn, contributed to the German decision to begin the Blitz, the 1940–1941 urban bombing campaign against London and other British cities. Although the risks can never be eliminated, the key to mitigating them lies in effective force management. Leaders must assess the potential costs of escalatory acts, establish appropriate rules of engagement, and enforce these rules among subordinate forces. The risk of accidents is further reduced with diligent training and exercise before engagement and effective command and control throughout the operation.

Ironically, escalation dominance is easiest to achieve against adversaries who pose the least threat of escalating a conflict.

Escalation Dominance Is Not a Reliable Means of Escalation Management

Some military and political leaders believe that U.S. forces can manage the above risks by achieving *escalation dominance*—the condition in which one side in a conflict has such a preponderance of military strength that it can set the pace for how the conflict develops. History, however, suggests that escalation dominance is difficult to achieve against a committed adversary, who may respond to such efforts by seeking ways to mitigate his opponent's advantage, prolong the conflict, or develop his own strengths.

When escalation dominance does occur, it is often the result of a combatant discovering and exploiting an opponent's vulnerability, such as high casualty aversion combined with low stakes in the conflict. Some adversaries have been able to offset U.S. conventional superiority in this way, as when Lebanese terrorists bombed the U.S. embassy and Marine barracks in Beirut in 1983. The attacks resulted in the withdrawal of U.S. forces from Lebanon. Ironically, escalation dominance is easiest to achieve against adversaries who pose the least threat of escalating a conflict—those with limited conventional capabilities and no nuclear weapons. Against an enemy that possesses even a few nuclear weapons, a strategy based on escalation dominance is *more*, not less, likely to result in catastrophic escalation.

Technology Can Accelerate Escalation and Create Escalation Dilemmas

While escalation is a product of human interaction, technology can act as an accelerant. Any technology that enables a military force to fight with more speed, range, and lethality will enable that force to cross escalation thresholds faster. Moreover, deploying threatening technology to vulnerable areas before or during a crisis could leave the United States open to an escalatory preemptive attack. On the other hand, lacking certain capabilities may prompt adversaries to escalate in such a way that the United States cannot respond proportionally. Leaving such options as the use of chemical or

biological weapons available to adversaries risks exposing the United States to an escalation dilemma that would force leaders to choose between allowing an enemy escalation to go unanswered and responding in a disproportionate way that is politically costly and escalates the conflict even further.

Escalation Management Today Requires Tailored Strategies

Given the dynamics described above, how can the United States mitigate the risks of escalation in today's security environment? The specific strategies will depend on the kind of adversary the United States faces, as these examples illustrate.

Threats of punishment do not appear credible to elusive individuals and groups that reject the established order.

A Sino-U.S. Confrontation Would Present Significant Risks of Inadvertent Escalation

Operational military doctrines in both China and the United States emphasize surprise, speed, and deep strikes to seize the initiative and achieve dominance. Neither body of doctrine appears to consider how an adversary might react to such operations in a limited war. Indeed, each seems to assume that it will suppress enemy escalation by dominating the conflict. Managing escalation in a limited conflict with China would require U.S. leaders to take a firm hand:

- controlling their own military forces, both to preserve China's critical escalation thresholds and to avoid accidental escalation
- clarifying U.S. thresholds and gathering intelligence on Chinese thresholds to avoid inadvertent escalation
- deterring potential Chinese efforts at deliberate escalation, fortifying the deterrent strategies as much as possible via defensive capabilities to deny China success and benefits from attempted escalation.

Regional Nuclear Powers May Be More Provocative Than Established Powers

Emergent nuclear states are more likely to make catastrophic errors because they may overestimate the power of their arsenals to deter conventional conflict, may be unpredictable, may have bitter animosities with their neighbors and the West, and may have domestic problems that threaten their stability. The recommended U.S. strategy for managing escalation will resemble that used for other nuclear powers, but statements about thresholds and deterrent threats need to be more explicit to avoid potential miscalculations. However, no adversary can be expected to restrain itself if enemy leaders believe their survival is at stake. Therefore, the United States should balance its threats with the assurance that it will not cross certain enemy thresholds if U.S. thresholds remain intact. To prepare for such confrontations, the United States should focus on developing effective defenses against ballistic and cruise missiles and against clandestine means of delivering nuclear, chemical, and biological weapons.

Irregular Warfare Calls for Military Restraint to Avoid Escalation

The risks of escalation in irregular warfare are much broader and more diverse than was appreciated during the Cold War. Historically, states that have attempted to wield their overwhelming conventional superior-

During the first Gulf War, the United States warned Iraq that it considered the use of chemical weapons to be an intolerable threshold. Saddam Hussein refrained from using such weapons as those shown here, which were reportedly filled with the nerve agent sarin.

ity against nonstate actors often have not achieved their strategic objectives but rather have escalated the conflict in ways that advance the adversary's cause (as in Beirut in 1983 and Mogadishu in 1993). The most effective use of conventional forces has been to protect civilian populations threatened by terrorists or insurgents.

It is especially difficult to manage the risk of escalation against nonstate actors. Threats of punishment do not appear credible to elusive individuals and groups that reject the established order. The better strategy is to constrain and, ideally, eliminate the adversary's ability to escalate the fight without inflaming other actors in the environment, who may sympathize with the jihadist or insurgent cause if the United States takes too strong a hand. The United States and its allies should emphasize judicial and diplomatic actions and foreign assistance and should avoid militarizing irregular conflicts to the maximum extent possible. When military force is needed, the focus should be on providing security to civilians. Any employment of offensive force should be done with restraint and discretion to avoid antagonizing local populations. Failing to do so risks validating extremist propaganda and sowing the seeds of future escalation.

The Air Force Can Play a Role in Managing Escalation

Escalation management is largely a matter of sound policy and good strategy. While these functions lie mainly in the realm of political and joint military leadership, there are a number of things that the U.S. Air Force can do to organize, train, and equip its airmen to support these important tasks more effectively.

Identify and Resolve Potential Escalation Dilemmas

The Air Force should conduct a thorough assessment of current and future force structure to determine whether it provides the necessary

Forrest Morgan

It all fits together in the end.

Search the World Wide Web for "Forrest Morgan" and you are likely to find more Web sites devoted to judo, karate, and taekwondo than to defense analysis. Before he embarked on the academic path that culminated in his becoming a senior political scientist for the RAND Corporation, Forrest wrote a popular book on the philosophical roots of the martial arts. His goal was to go beyond the arena of competitive sports and to reclaim the principles that make the practice of martial arts a way of life. "The Martial Way . . . is a holistic discipline aimed at the pursuit of excellence, not just in the training hall, but at life," he wrote. "Its disciplines strive to apply the Way in every vocation, and its adepts tend to be achievers in any field of endeavor."

It is easy to see that Forrest has been following the "Martial Way" throughout his life. Whether as a martial artist, a lieutenant colonel in the Air Force, a professor at the Air University School of Advanced Air and Space Studies and the University of Pittsburgh, or a policy analyst at RAND, Forrest has been motivated by a common set of interests in strategic thought and by a willingness to set aside conventional notions of how things are done and to look at problems afresh.

This is an essential part of what distinguishes his work on escalation management from previous thought on the subject. During the Cold War, analysts sought to anticipate escalation pathways in specific conflict scenarios, the idea being that the United States could take a conflict to the brink of disaster in order to force the Soviet Union to back down. However, actual conflicts do not follow the predicted pathways, and the strategy of "brinkmanship" proved much less appealing after such near disasters as the Cuban Missile Crisis. Forrest seeks to understand the root causes of escalation in any given conflict, the goal being to restrain, if not to master, the forces that would otherwise do great harm.

Today, Forrest is applying this understanding to a study of how to better manage U.S.-Chinese military relations, where his knowledge of Eastern military thought lends additional insight to his work as a policy analyst. "My career has been like that," he remarks. "It all fits together in the end."

flexibility to offer joint commanders proportionate responses to potential paths of enemy escalation. When gaps are identified, the Air Force should program new capabilities to fill them. When fiscal or political costs might preclude developing certain weapons that potential adversaries possess (such as chemical or biological weapons), the Air Force should concentrate on developing defenses against them and should work with combatant commands to develop strategies to deter their use.

Train Air Component Commanders and Their Staffs on the Principles of Escalation Management

Air component commanders and their staffs have a responsibility to advise joint commanders and policymakers about the escalation risks associated with prospective courses of action. To prepare airmen for that responsibility, they should be taught that escalation management entails more than just establishing and enforcing rules of engagement. Determining enemy escalation thresholds should be an intelligence priority before and during the campaign planning process and should remain so as the fight progresses. Finally, commanders and planners should eschew plans that escalate in ways that offer tactical advantages at the risk of great strategic cost.

Codify the Principles of Escalation Management in Airpower Doctrine

The Air Force should revise relevant passages in its doctrine to better acknowledge the risks of escalation and the need to manage them. Doctrine should stress knowing the political limits of conflict and understanding why they are important. It should explain the relationship of thresholds to escalation and emphasize understanding the enemy's critical thresholds and how they can change over the course of the conflict. Finally, while the ability to impose shock, paralysis, and rapid dominance may be useful tools for the Air Force to bring to the fight, doctrine must acknowledge that these may not be appropriate tools for some limited conflicts.

Teach Escalation Management in Air Force Schools

The Air Force should provide all airmen a firm grounding in the concept of limited war, the risks of escalation, and the principles of escalation management. These topics should be stressed in professional military education programs and at the School of Advanced Air and Space Studies. They should also be emphasized in war games and exercises.

Keeping Limited War Limited

Military conflict always represents a crossing of boundaries from control to crisis. It is impossible to exercise complete control over how the crisis will unfold. Yet, by understanding the mechanisms behind escalation, it is possible to increase the chances that a limited war will remain limited and that the scale of the conflict will be appropriate to achieve the United States' strategic aims.

For more information, see

MG-614-AF, *Dangerous Thresholds: Managing Escalation in the 21st Century*, by Forrest E. Morgan, Karl P. Mueller, Evan S. Medeiros, Kevin L. Pollpeter, and Roger Cliff. Online at http://www.rand.org/pubs/monographs/MG614/

Project AIR FORCE Research Excellence Award

Project AIR FORCE (PAF) has instituted a new award to honor researchers who, year after year, have achieved the highest degree of excellence in their work. Winners receive support for professional development and a plaque recognizing their outstanding contributions.

The selection committee includes the unit director, Andrew Hoehn, the associate director, Cynthia Cook, and the director of staff development, Michael Kennedy.

PAF congratulates the 2008 Research Excellence Award winners, Robert Leonard, William Stanley, and Robert Tripp, on their record of outstanding accomplishments.

Robert Leonard

Robert Leonard is a cost analyst currently leading a PAF study of growth in acquisition costs and schedules for major defense systems. Since joining RAND in 1992, his research emphasis has been on acquisition policy and cost analysis. His work has covered a broad cross section of topics in military resource management, including in-depth case studies chronicling and assessing innovative acquisition processes for groundbreaking weapon concepts; analyzing the costs and cost-effectiveness of multiple future force mixes with differing emphases; contributing the cost analysis elements to high-profile analyses of alternatives; and conducting multiple studies of the magnitude, trends, and sources of cost growth in major defense acquisition programs.

Rob's most recent work involves systems that began development during the post–Cold War era, when acquisition reforms were coupled with the "peace dividend" to dramatically reduce available resources, and system development efforts that began in the post-9/11 era, when available resources greatly expanded. Rob received his B.A. in economics from the University of California at Los Angeles.

William Stanley

William Stanley is a senior engineer currently leading combat aircraft force modernization and employment studies for PAF. At RAND since 1972, he has participated in and led research projects covering a broad cross section of military and civil topics, including airpower force employment; weapon system acquisition; aircraft technology assessment; aircraft accident investigation; and examinations of space, energy, transportation, and air pollution policies. His recent studies have included an examination of aircraft weapon employment and aircraft survivability in Operation Allied Force; characterizations of antiaccess threats; the role of long-range strike systems; and the potential for using smaller, lower-cost aircraft systems for counterinsurgency operations. His latest research addressed aging issues associated with the Air Force's C-130 fleet of intratheater airlifters.

Bill received his B.S. in aerospace engineering from the University of Texas at Austin and an M.S. in engineering from the University of California at Los Angeles.

Robert Tripp

Robert Tripp is a senior policy analyst currently leading multiple PAF analyses in the resource management area. Bob has been with RAND for 15 years, and his work has covered a broad cross section of topics in military resource management, including evaluation of repair network options that provide the business case for the repair network transformation initiatives the Air Force is implementing. Bob has also led a project to identify combat support needs in future environments beyond Iraq and Afghanistan. These analyses show that combat support resources might be critical elements of reenergized training, equipping, assisting, and advising roles designed to prevent the outbreak of full-scale contingency operations. Bob has also led efforts to evaluate options for how the Air Force might best present command and control of air, space, and cyber forces to combatant commanders.

Bob received a B.S. in metallurgical engineering and an M.S. in business administration from Michigan Technological University. He was awarded a Ph.D. in business administration from the University of Minnesota.

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